SKETCHES

OF

THE PHYSICAL GEOGRAPHY

AND

GEOLOGY

OF

NEBRASKA.

BY

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PREFACE.

THE continual demand for some of my papers on the geology of Nebraska, now out of print, suggested the preparation of this volume. It includes in a revised form the most important of my publications on our geology. The greater part of this work, however, is entirely new, and includes many facts and observations now for the first time made known. I had intended to give a much fuller treatment of the Loess deposits and period, but the materials have accumulated to such an extent that it was thought best to reserve them for a separate volume. In preparing this work I have always kept in mind the many letters of inquiry continually being received about the State—such questions as are most frequently asked of a naturalist about Nebraska. Only a small part of the State has received a detailed geological examination, and therefore many material points could barely receive mention. In the sketches of our geological history, I have attempted to give an idea of the chain of events that resulted in the present order of things in Nebraska. My conclusions on many points are very different from others, but I have come to them by a careful study of our geology for fifteen years, with all the means which I could command. Wherever I have used the works of others it is acknowledged in the text. It is possible that there are omissions of this kind, as I may not always have remembered whether myself or another first observed a fact or discovered a principle. All such omissions, if any, are unintentional. It was intended to include a new geological map of the State in this work, but I have not been able to satisfy myself about the accuracy of some of the boundaries of geological formations, and therefore postpone its publication till spring.

I am under obligations to Prof. C. D. Wilber for important suggestions; and to many persons over the State, whom I cannot mention in detail, who have provided me with specimens from their localities. I am also under great obligations to the Burlington & Missouri River Railroad in Nebraska, to the Union Pacific Railroad, to the Atchison & Nebraska Railroad, and to other roads for transportation and other favors. Without the aid thus received, it would have been impossible to make many of the investigations included in this work. Wherever I have gone in the State I have received all possible help from the people in making geological and other natural history examinations. Hoping that this work will help others to understand the physical conditions of our State, and stimulate an interest in our natural history, I submit it to the people of Nebraska.

SAMUEL AUGHEY.

UNIVERSITY OF NERRASKA, Janu3ry 1st, 1880.

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PART FIRST.

PHYSICAL GEOGRAPHY.

PHYSICAL GEOGRAPHY.

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NEBRASKA occupies a position near the centre of the Republic. The parallel of 40° is its southern boundary, and the Missouri River, the Niobrara and the Keya Paha rivers form the Northern boundary as far west as range twenty west of the sixth principal meridian. West of this point the parallel of 43° forms its northern boundary. Its eastern boundary is the Missouri, whose direction here is a little east of south. This brings the southeast corner of the State to the 95° 25′ meridian. The 104 meridian west of Greenwich marks its western boundary down to latitude 41°. Below this point a line a few miles west of the 102° meridian constitutes the western boundary of the State. This notch takes out of the southwest corner of the State, 7,300 square miles. Were it not for this offset the State in shape would approximate to a parallelogram. The extreme width of the State from north to south is 208.5 miles, and its length from east to west is within a fraction of 413 miles. In area the State approximates closely to 75,995 square miles, or nearly 48,636,800 acres. Taking Ohio, which has an area of 39,964 square miles, as the type of a model sized state, it is seen that Nebraska contains almost twice as much territory. The area of Nebraska is 12,359 square miles larger than all the New England states combined. It contains 20,000 more square miles of territory than Iowa. England and Wales combined have less area by 17,000 square miles than Nebraska. In extent of territory it is an

empire, and yet as we shall see hereafter, few states have really so little waste land as Nebraska. It lies in the same path in which the currents of emigration have been flowing—in the line of the great States of the Union, and must in the nature of things receive their overflow of population.

Surface of the State.

The surface of Nebraska is exceedingly varied. There are indeed no elevations that can be dignified with the name of mountains, but in the northern and western parts of the State there are lofty hills of very varied character. Generally the ascent is gentle, though occasionally it is precipitous. Unlike the ridges of the east which are so generally the result of elevations and subsidences of the earth's crust modified by subsequent aqueous agencies, the hills and rolling lands of Nebraska are mostly wholly caused by erosion. In the east the body of hills is mainly made up of massive rocks, here it is partly composed of loosely compacted drift materials, but mainly of Loess. In fact, Nebraska emerged so recently geologically from the waters of the Loess age, that it still exhibits as a whole many of the phenomena of a recently drained lake bed. The gently rolling lands of three-fourths of the State appear very much like the suddenly petrified waves and billows of the ocean. Sometimes extensive stretches of surface are met with that appear to be level, but closer observation shows even these to be gently undulating. From these last mentioned forms to the few isolated sections of limited extent,broken by canyons with precipitous sides, the transition is gradual. Every shade of form and surface connects the two varieties of relief. The

Bottom Lands

are the most conspicuous modifying feature of the landscape of the State. In crossing the State at right angles to the direction of the streams, the bottom lands are met with every few miles. They are huge, generally shallow troughs, in breadth proportionate commonly, to the size of the streams. They range in width from a quarter of a mile on the smaller streams to twenty-three miles on the Platte and the Missouri. They are frequently terraced, and the terraces like broad steps gradually lead to the bordering bluffs which in turn are very varied in height and form. Frequently the low terraces on the bottoms have had their edges so worn away that their character is concealed. What was once a terrace has become a gentle slope.

A good example of this character are the slopes on the bottoms between Crete and Beatrice, and between Ashland and Lincoln. The bottoms with their bordering lines of bluffs wind and vary in direction as much as the serpentine movements of the streams themselves. The bluffs are steepest and roughest on the Missouri, especially towards the north line of the State. On the middle Niobrara they frequently assume the exceptional character of borders to deep canyons. Even on the Missouri there are very few that cannot be successfully cultivated. Occasionally it is hard to tell where the bottom ceases and the bluffs begin. This is owing betimes to the terraces that ascend the bluffs, and sometimes to the lowness of the bluffs whose rounded outlines like the sides of a shallow basin merge gradually into the bottom. Sometimes the wind has worn the sides of a bluff into stair like forms. The observer not infrequently meets portions of a bluff standing out in isolated, perpendicular walls like huge battlements. The innumerable tributaries that creep quietly and unexpectedly into the main bottoms complicate still further these forms of landscape. The traveler with poetry and art in his composition is often tempted to ascend a bluff adjoining a valley, which lying at his feet, enables him to trace it as far as the eye can reach. The upland plain on the other side, whose inequalities are wavelike, gives a sharply outlined background to the picture of the valley. He is at a loss to which to assign the palm of greatest beauty. The effect is intensified when upland and valley are dotted with homesteads and cultivated grounds. The quiet beauty that comes from human industry then blends with the sublimity of nature.

The dominant geometrical form observed in the forms of the surface is the curve. The observer never gets outside of curves. They intrude themselves everywhere. They are not uniform monotonous curves, but curves infinitely varied. Rarely is a straight line needed to relieve from sameness, but when it is needed it is there. The streams, the terraces, the bluffs, the valleys themselves all follow curves. There are short curves and long curves; regular and irregular curves; infinitely varied, seemingly in confusion, but all full of profound expression—the expression of matchless beauty. " The curve is the line of beauty." Here nature has put forth her best efforts to exemplify this law. No artist has yet successfully painted Nebraska scenery. It still awaits the master mind who can catch with his artist's eye these superb forms of

quiet beauty and place them on canvass. A remarkable feature is the commonness of beautiful landscapes. Almost every mile along the river valleys affords them. The bottoms along the bluffs at every turn are sculptured with beautiful coves, which, sheltered from wind and storm, afford favorite building spots for many people.

Elevation of Nebraska.

The greater part of Nebraska is a plateau. This will be apparent by an examination of the following list of elevations above the sea level. For convenience the elevations are given, first in lines running along the Missouri, and then in lines running east and west. Those marked with a star were taken by myself with a barometer and are only proximately correct. Those along the Republican Valley from Orleans westward, were taken by D. N. Smith, Esq., of Burlington, Iowa, and I have reason to believe from observations taken with him that they are proximately correct. The observations in northwestern Nebraska not marked with a star were taken by Captain W. S. Stanton, of the engineer corps, U. S. A. The remaining determinations of heights have been taken from the railroad surveys of the State. The e'evations are in feet.

Southeast corner of the State on the bottoms at the mouth of the Nemaha River	*878
Brownville	919
Nebraska City	964
" " at low water of the Missouri	919
Plattsmouth	984
Omaha, U. P. Depot	1,056.26
" low water of Missouri	983.26
" high " " "	1,002.26
Blair	1,111
Tekamah	*1,040
Decatur	*1,052
Dakota City	*1,069
Ponca	*1,178
St. James	*1,185
Green Island	*1,204
Niobrara	*1,240

Elevations Near the South Line of the State.

Falls City	904
Beatrice	*1,278
Fairbury	1,324

Belvidere	1,509
Red Cloud	
Bloomington	
Orleans	2,150
Arapahoe	2,250
Indianola	2,600
Culbertson	2,760
State Line	3,600
Head of the Republican in Colorado	4,050

Elevations Along the Line of the B. & M. R. R. in Nebraska.

Plattsmouth	984
Omaha Junction	1,001
Louisville	1,041
South Bend	1,002
Ashland	1,102
Greenwood	1,141
Waverly	1,137
Lincoln	1,164
Highland	1,429
Crete	1,369
Dorchester	1,502
Fairmount	1,657
Harvard	1,815
Juniata	1,985
Kenesaw	2,064
Lowell	2,086
Kearney Junction	2,163

Elevations on the B. & M. R. R. from Nebraska City to York, via Lincoln.

Nebraska City	964
Dunbar	1,069
Syracuse	1,064
Palmyra	1,154
Bennett	1,154
Cheneys	1,444
Lincoln	1,164
Woodlawn	1,194
Germantown	1,584
Seward	1,449
York	*1,473

Elevations on the Line of the Atchison & Nebraska Railroad.

Rulo	*887
Falls City	904

Salem	917
Humboldt	989
Table Rock	1,036
Tecumseh	1,120
Sterling	1,193
Summit	1,375
Lincoln	1,164

Elevations Along the Line of the Union Pacific Railroad.

Omaha, Union Pacific R. R. Depot	1,056
Papillion	1,009
Elkhorn	1,187
Fremont	1,220
Schuyler	1,372
Columbus	1,469
Clarks	1,647
Lone Tree	1,723
Grand Island	1,887
Wood River	2,011
Gibbon	2,083
Kearney	2,143
Elm Creek	2,278
Plum Creek	2,406
Willow Island	2,547
Bradley	2,673
North Platte	2,825
O'Fallon's	3,012
Alkali	3,074
Ogalalla	3,225
Brule	3,301
Julesburg	3,535
Lodge Pole	3,835
Sidney	4,108
Antelope	4,747
Pine Bluffs	5,061

Elevations Along the Line of the Fremont, Elkhorn and Missouri Valley Railroad.

Fremont	1,220
Nickerson	1,222
Hooper	1,248
Scribner	1,227
Crowell	1,296
West Point	1,337
Wisner	1,404
Norfolk	*1,428

Elevations Along the North Line of the State.

Niobrara	*1,240
Mouth of Keya Paha	*1,960
Mouth of Snake River	*2,690
Camp Sheridan, Old Spotted Tail Agency	*3,490
Camp Robinson	3,764
State Line on Cottonwood Creek	3,781
Indian Creek, northwest corner of State	4,013
Scott's Bluffs, thirty miles north of Pine Bluffs	*6,051
Clark's Bridge, north of Sidney	3,707
Niobrara River, southeast of Fort Robinson	4,118
White Man's Fork on State Line, south of U. P. R. R.	3,188

From the preceding data it is estimated that the eastern half or the State along the line of the Union Pacific Railroad has an average elevation of 1,700 feet, the western half 3,525 feet. The average elevation of the whole line would be 2,612 feet.

Along the south line of the State the elevation of the eastern half averages 1,200 feet; the western half 2,672 feet.

Along the north line of the State the data given makes the eastern half beginning at Ponca 1,353 above the sea level. The western half averages about the same as that of the line of Union Pacific Railroad. It is proportionately greater along its middle and less along its western portion. This would give an elevation of 2,312 feet for the whole State. This is a much smaller elevation than is usually given for the State, but it is the more accurate because based on elevations along the north and south line, as well as through the centre of the State from the east to west. Estimates heretofore made place the mean elevations at 2,550 feet.

For the first one hundred miles west from Omaha the ascent is at the rate of five and a half feet to the mile. The second hundred miles increases the ascent to seven feet; the third hundred, seven and a half feet, and the fourth hundred to ten and a half feet to the mile. The ascent on the last fifty miles on the west end of the State is eighteen feet to the mile. While these figures are not exact they are close approximations to the truth. The calculation has been made for the line of the Union Pacific Railroad, but the south line of the State differs very little from this. A similar gradual ascent characterizes the northern line of the State. It will be observed that the second and third hundred miles have almost the same gradual ascent. After this the ascent increases quite rapidly until it reaches eighteen feet to the mile. The

increase of elevation going north and west on the eastern boundary of the State along the Missouri is much less. Taking the mouth of the Nemaha as our starting point, whose elevation is 878 feet, and comparing it with the elevation of the Missouri bottom at Omaha, which is 1,002 feet we have a difference of 124 feet, or a rise of one and a fourth feet to the mile. The fall between Omaha and Dakota City is even less than this.

In western Nebraska the difference in elevation between the south line of the State and the Union Pacific Railroad approximates to 352 feet. On the west line of the State the ascent continues going north until at Scott's Bluffs an elevation of 6,051 feet is reached. Although this is only approximately correct, as I took the observations with a barometer, yet there is little doubt that this is the highest point in the State. From here there is a gradual descending slope to the north line of the State with some intervening inequalities and depressions in the valleys of the Niobrara, the White Earth, and Indian Creek. From the Republican River on the West line of the State to Big Springs in the same meridian on the Union Pacific Railroad there is an ascent of 352 feet. From this latter place there is a still further rise of 283 feet to the Niobrara River, or a total ascent along this line from south to north of 635 feet, against a corresponding difference of less than 200 feet along the eastern border of the State. It will also be remembered that the lowest part of the State is its southeast corner, and the highest part is a point north of the Union Pacific Railroad on Scott's Bluffs. Take the State therefore as a whole and it will be seen that it slopes mainly toward the east and in a minor degree toward the south. The only exception to this rule is the extreme western line of the State, where the Colorado notch has taken from Nebraska territory a section which legitimately should belong to her. Because of this shortening of our southwestern border, Pine Bluffs, the last station of the Union Pacific Railroad in Nebraska is near the south line of the State. From here the ascent toward the north continues only for about thirty-six miles to Scott's Bluffs from which there is a gradual descent to Indian Creek near the northwest corner of the State. But eastward from this point the descent is generally south and still more east. As would be expected from such relief forms the great majority of the tributaries of the main streams, except those of the Niobrara, flow towards the southeast. Prof. Wilber has remarked that lines drawn along the main divides of the State on any

map would enclose the drainage systems in forms resembling huge bags. The open end representing the mouths or lower ends of the rivers will face the east or southeast.

How to Gain a Conception of Nebraska Topography.

Conspicuous as are the valleys of Nebraska no good idea of its topography can be formed by following them exclusively. Thousands pass through the Platte Valley from east to west without comprehending the physical features of the State. In fact, I have met many old freighters across the plains who entirely mistook its character, because they had followed mainly the valleys. This, too, is one cause for the misstatements of tourists, who have described Nebraska as a monotonous, level plain.

To gain a clear conception then of Nebraska topography, one must cross the valleys and divides nearly at right angles. In doing this it will be observed that the most rolling lands generally border the valleys or bottoms. Advancing, the rolling and sometimes broken character gradually disappears when the divide is reached which separates the last from the next drainage system. Here the land swells out into a gently undulating plain that varies extremely in extent. The extent of such a divide may be limited to a half mile or may extend for thirty or more miles. These swells or long tongues of undulating lands are found on the divides between nearly all the rivers of the State. Occasionally between the lesser streams a single low bluff, a few hundred feet wide, and only slightly raised above the general level, marks the divide. Among the most conspicuous of these divides are the beautiful uplands between the Republican and the Platte, between the Platte and the Blue Rivers, and between the forks of the Blue Rivers. Between the Blues and Nemahas, and between the forks of the latter similar divides exist. North of the Platte, conspicuous for their beauty, are the divides between the forks of the Elkhorn, and at the headwaters and between the forks of the Logan, and between the Elkhorn and the Loups. In fact they are met with between most of the streams of the State. Some of these high uplands have great numbers of shallow basin-shaped depressions whose soil and grasses closely resemble those of the bottom lands. They are evidently the remains of lakes that until recently occupied their sites. Indeed some of them still retain this character, being filled with water the whole year round, varying from one to ten feet in depth.

Between these last and swamps and bogs, every kind of transition form is found. Fillmore, Clay, York, Hamilton, Franklin, Phillips and Wayne Counties have a notable number of these old lake beds.

Number of Nebraska Valleys.

Nothing is more surprising to one who studies the relief forms of the State than the amazing number of valleys or bottom lands. Some writers have stated that there were several hundred. It would have been more correct to have reported several thousand. Take the region of the Republican as an example. On an average a tributary valley comes into the main bottom from the north side every two miles. Now as this river flows for two hundred miles through the State, it would give one hundred for this section alone. Counting, however, the streams that come in from the south side, and those flowing into its larger tributaries, this number should be multiplied by at least four, giving four hundred valleys great and small for this region alone. Now add to these valleys those that are tributary to the Platte, the Blues, the Nemahas, the Elkhorns, the Logan, the Bows, the Missouri between its larger tributaries, the Niobrara and the Loups, and it will increase the number to thousands. It is true that many of them are narrow, ranging from one fourth to a mile in width, but still they are valleys with living or extinct stream beds in the middle or towards one side of them, and having all the physical features of the larger river bottoms. As already intimated there are a few minor valleys among the smaller tributaries of the upper Elkhorns, Bazile, Loups, Niobrara and Republican, in the stream beds of which the water no longer flows, but as will be shown further on many of them are regaining, and all of them will in time, their former supply of water. Thus can be seen why over the larger part of Nebraska the settler can have his choice between bottom and upland. The great body of these bottom lands, though composed of the richest mould and modified alluvium and Loess materials are perfectly dry. It is true that swamps are occasionally met with, but they occur at long intervals and are the exception.

No one can gain any idea of the number of these bottom lands by looking at a map. Neither can they be found on the plats of the government surveys, though in the latter they are more fully given than in the former. In fact, counting in the small tributaries with their narrow bottoms, not less than twenty-five per cent of the

entire surface of the State is made up of bottom lands. This is a higher estimate than I formerly made, but I have come to it by increased study of the physical features of the State.

Exceptional Features of the Niobrara River Region.

The Niobrara River is the least known of all the drainage systems of the State. It deserves to be better known, and in the near future will be visited and studied by the geologist and the artist. It holds concealed many unrevealed wonders for the student of nature and of art.

For the first ninety miles from its mouth the Niobrara is not greatly different from other Nebraska rivers, save in the exceptional rapidity of its current, and its sandy flats and numerous islands. Its bottom is also narrower in proportion to the size of the river than other streams of the State.

In going up the valley it is observed to change rapidly at about longitude 99° 20′. The bluffs contract and become lofty. In fact, the river here flows through a deep canyon. It retains this character for the next 180 miles or to about longitude 102°. The sides of the canyon are often three hundred and sometimes four hundred feet high. The walls are mostly composed of silicious, and yellowish, whitish and calcareous rocks. They are often capped with a hard grit which preserves their vertical character, and often causes them to be undermined and assume an umbrella form. In this canyon region it is next to impossible to follow along the immediate banks of the river, owing to the numerous isolated buttes and walls that rise perpendicularly from near the water's edge, making walls across the line of travel hundreds of feet high. No indication of the river's existence is here given in approaching it from either side, except by the trees that sometimes rear their tops above the canyon, and which grow near the water's edge. The sides of the canyon are worn into innumerable labyrinths by the numberless springs that have been, like the main river, chiseling the rocks for ages. These lateral canyons are exceedingly mazy in their windings. Nowhere else have I ever seen such cool, clear, strong and sparkling springs as here abound. Their number is astonishing. They are met with in places for miles every few hundred feet or yards.

At the lower end of this canyon region the rocks are of cretaceous age. Towards the west end the cretaceous becomes covered with tertiary rocks. Vegetation in the canyons of the Niobrara is

prolific. In places pines and cedars abound. Near the east end of the canyon region the oak,ash, cottonwood and elm,and occasionally box elder are intermingled with pines—which sometimes, however, are entirely wanting. Grass, too, is abundant. Here formerly was the paradise for elk, deer and antelope, wolves and foxes. Food and shelter, the agencies most important to preserve brute life was specially abundant. No wonder that the Indian tenaciously clung to this region. Here the chase always supplied him with abundance of food. To him it was also consecrated ground. Here in the labyrinthine canyons among the trees, druid like, with the light of the sun shut out, he communed with the shades of his ancestors. Here he heard as he did nowhere else the voice of the Great Spirit in the rustle of the leaves and the sighing of the winds.

Where the river enters the canyon it is about eighty-two yards wide. It narrows towards its source, and before the west line of the State is reached it is reduced in breadth to ten or fifteen feet. The water, however, is remarkably clear and cool. Above the canyon the valley is well covered with grass and a great abundance of rushes. Wood, however, in this part of its course is rare.

A large part of the entire middle portion of the Niobrara River, as first observed by General Warren, flows lengthwise of an anticlinal ridge. In the canyons, for example, the rocks dip away from the river on each side. In places where I had opportunity to measure the angle their inclination away from the stream amounted to from ten to fifteen degrees. It is probable that the river has been outlined only since the close of the submergence that attended the glacial age. Flowing along this anticlinal ridge when it first emerged it has continued in its old rut as the continent was rising, cutting down its bed about as rapidly as the uplifting took place. It is probably a continuation of some uplift and break eastward from the mountains similar to the one seen near Camp Robinson. Over a portion of the western end of the Niobrara River this anticlinal ridge on top of which it flows is not visible. The cutting of the river still continues, but its rate is uncertain but probably about a foot to the century.

As would be expected the tributaries of the Niobrara that flow into it from the north or south are very short. The larger ones invariably flow parallel or nearly so to it. The Keya Paha and Snake River are the most conspicuous instances. I have no doubt that hereafter it will be found that the Keya Paha occupies a

depression beyond the anticlinal ridge along which the Niobrara flows. In the canyon region, in going to the Niobrara, when within twelve or fifteen miles of it I invariably found myself going up hill. It was rarely sensible to the eye, but the barometer noted it distinctly. When the river was reached it lay from one hundred and fifty to four hundred feet below. On the north side it was again down hill for a short distance. Some of the head waters of the Loup originate close to the Niobrara, because of this ridge on top of which it flows. This makes it impossible to drain much of the country from the south. For the exceptional meteorological conditions here the reader is referred to Chapter III.

SAND HILLS.

South of the valley of the Niobrara and its canyons, and commencing about longitude 100° are the far famed Sand Hills. The sands of these hills are partially moveable. Where they monopolize the ground travel is difficult, both because of the inequalities of the ground and their shifting character. They vary in height from a few yards to several hundred feet. Their shape approximates the conical form. A curious character of these hills is the conical depression so frequently found on or near their summits which are made by the winds. Many of these have the form of craters. Sometimes these crater-like excavations occur on the sides of the sand hills. Indeed almost every kind of wind sculpturing occurs among them, and the observer is surprised at every step at the strange forms that meet him. It is a fine field for the study of the opposite effects on landscape of wind and water agencies. Such crater-like holes freshly formed are destitute of vegetation. Formerly these "barren holes" were abundant in the sand hill regions. Now the great body of them are grown over with grass, and new ones in process of forming are only met with at longer intervals. But by no means is so large an extent of country covered by them as is sometimes represented. In going southward from the Niobrara after wandering among the sand hills for ten or fifteen miles they are found often suddenly to cease, and a grass-covered prairie of great richness to take their place. There are also extensive sand hills at the head of the Loups. Between these sections there is generally a gently rolling prairie with occasional sand hills dotted over them. There are also sand hills south of the Platte from Kearney eastward several miles in width, and on the upper Repub-

lican. The character and origin of these sand hills will be discussed in the chapter on the superficial geology of the State. Suffice it here to say that these sand hills are being covered by the increasing rainfall of the State with nutritious grasses, and are becoming fine grazing grounds. While principally composed of sand they also contain a large amount of potash, soda and lime, and these fertilizers start vegetation as soon as there is a sufficiency of moisture.

Bad Lands.

The bad lands run into northwestern Nebraska, but cover a very limited area mainly beyond the White River. They are made up of indurated sands, clays and marl, and occasional layers of thin hard rock. They have been cut up into deep canyons and ravines by atmospheric agencies. The sides, until the talus at the bottom is reached, are often vertical and sometimes capped at the top with a hard rock that projects beyond the sides. Often without a particle of vegetation the isolated cones, columns and peaks look in the distance like towers, pyramids, cathedrals and obelisks, resembling the ruins of the old cities of the Orient. The geological age and the character of the fossil plants and animals will be discussed in the chapter on the Tertiary Age.

CHAPTER II.

CLIMATOLOGY OF NEBRASKA.

Temperature—Tables of Temperature—Mean Temperature of Summer, Winter and Spring—Bulletins—Autumns—Mean Temperature of the Year—Extremes of Temperature—Winds—Storms of Winter—Purity of the atmosphere—Ozone.

THE factors that enter into the determination of climate are temperature, forms of relief, condition of the atmosphere, geographical position and rainfall. Before giving the characteristics of the climate of Nebraska, it is important to look at the most important facts that produce them. For this purpose the following meteorlogical tables are introduced.

Temperature.

There has been much misapprehension about the temperature of Nebraska. Sometimes it has been represented as possessing a semi-arctic climate; and again that its summers are of a torrid character. To show the real facts in the case, the following tables of daily temperatures for a year are given from the reports of the Signal Service. The stations are on the U. P. R. R., three hundred miles apart, and approximate closely to the mean temperature for the whole State.

In addition to the tables of the Signal Service, no exhibit would be complete without the results obtained by Dr. A. S. Childs, of Plattsmouth, one of the most careful, conscientious and accurate scientific observers in any country. He has been constantly reporting, first for the Smithsonian and then for the Signal Service, since 1866. Prior to that year he had also been reporting at intervals. The tables prepared by him follow these two from the Signal Service.

Maximum, minimum, and mean temperatures.— Station, Omaha, Neb.

Day of Month.	1877. July. Max.	July. Min.	Aug. Max.	Aug. Min.	Sept. Max.	Sept. Min.	Oct. Max.	Oct. Min.	Nov. Max.	Nov. Min.	Dec. Max.	Dec. Min.	1878. Jan. Max.	Jan. Min.	Feb. Max.	Feb. Min.	March. Max.	March. Min.	April. Max.	April. Min.	May. Max.	May. Min.	June. Max.	June. Min.
1	79	62	87	66	70	58	64	52	46	37	32	5	34	24	37	24	52	44	59	39	58	50	86	66
2	83	64	87	67	70	50	72	56	46	34	47	20	28	10	34	15	44	33	56	42	68	49	79	66
3	89	63	83	61	76	51	64	41	49	34	40	26	33	13	35	9	38	28	56	34	60	41	73	57
4	94	74	83	68	76	56	57	33	40	27	39	30	17	Z'ro	43	16	51	22	62	35	63	38	75	54
5	96	75	83	69	78	58	55	42	29	15	30	25	20	9	48	33	63	36	64	42	74	43	77	56
6	96	74	85	64	77	60	62	46	40	16	38	20	11	Z'ro	50	40	61	43	60	35	82	57	75	63
7	99	77	87	67	78	60	66	49	42	34	44	26	34	3	49	32	66	38	57	43	68	53	64	52
8	88	70	81	66	75	64	67	38	36	26	39	23	44	30	37	28	65	50	59	42	71	51	59	48
9	84	67	81	61	67	60	60	47	26	20	48	32	51	30	29	24	56	44	58	36	60	44	67	46
10	81	67	93	65	72	55	59	38	42	20	54	31	31	23	31	18	52	42	52	39	63	37	73	48
11	78	60	87	73	77	57	63	42	53	30	57	31	50	23	43	18	57	34	66	38	51	39	77	52
12	85	66	84	69	85	62	73	55	54	35	52	40	40	31	44	32	52	38	67	47	55	33	75	59
13	88	67	74	58	86	72	70	55	57	42	49	33	33	26	38	30	49	35	56	44	58	46	64	60
14	92	71	79	56	79	61	64	48	52	41	49	31	29	12	39	34	56	38	48	42	60	47	75	60
15	82	71	79	56	75	54	48	40	54	31	57	33	37	9	45	34	68	44	57	43	60	48	75	63
16	85	66	77	59	69	56	50	44	61	40	49	31	45	20	43	33	56	35	69	52	56	46	74	56
17	80	66	80	60	65	44	57	45	52	34	57	38	48	30	40	30	56	32	74	56	55	46	79	59
18	76	64	81	60	75	46	51	47	51	39	59	40	49	30	54	35	61	38	69	48	68	52	82	62
19	69	69	83	62	80	49	50	44	51	38	46	37	44	40	61	40	72	47	65	47	66	48	86	64
20	73	56	74	65	79	52	44	35	51	34	61	41	40	28	49	35	68	46	71	43	65	48	76	60
21	79	53	70	56	79	57	55	34	47	37	60	49	43	25	47	32	58	46	82	60	68	45	77	57
22	83	57	74	49	81	64	64	39	49	29	59	52	37	24	46	32	62	50	76	55	65	57	81	56
23	85	58	76	53	79	54	66	44	49	33	54	38	36	17	40	30	74	49	63	46	78	62	89	63
24	85	62	79	59	80	67	70	47	47	40	43	37	44	28	36	28	53	35	65	45	80	53	83	66
25	86	66	77	61	79	64	61	44	44	35	37	27	32	19	44	25	61	36	68	45	73	57	78	64
26	89	66	85	66	73	62	63	48	37	30	37	30	41	23	50	25	80	50	67	43	73	49	83	57
27	87	68	84	71	70	57	60	43	33	21	38	32	45	21	58	34	66	40	67	44	73	52	86	64
28	83	63	82	70	81	55	54	40	22	9	39	33	33	23	61	42	46	31	71	45	76	56	78	71
29	87	64	84	68	86	64	51	36	15	−2	34	27	31	27	..	..	45	35	75	49	72	60	84	66
30	85	67	91	73	81	61	50	33	22	6	34	26	35	25	..	..	42	33	68	52	69	55	79	63
31	89	70	84	68	..	..	53	30	..	..	37	20	35	18	..	..	59	34	..	..	73	58	..	..
Range	46°		44°		42°		43°		63°		56°		51°.9		52°		58°		48°		49°		43°	
Monthly Means	79°.0		73°.2		*66°.6		51°.1		36° 3		39°.2		28°		36° 9		48° 1		55°.0		58° 5		68° 4	

*Thirty days only.

Maximum, minimum, and mean temperatures.—Station, North Platte, Neb.

Day of month.	1877.												1878.											
	July.		Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.		March.		April.		May.		June.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	79	53	91	61	75	52	72	38	43	29	50	11	21	0	29	25	39	32	61	28	57	50	82	63
2	84	48	90	60	73	52	75	43	52	22	53	15	20	– 1	44	27	49	31	56	32	60	44	72	52
3	94	55	83	65	64	54	63	34	45	28	37	20	25	3	50	20	49	27	59	3.	59	33	70	46
4	102	65	78	61	79	49	58	25	35	22	31	24	16	– 8	60	24	62	28	75	35	68	32	76	45
5	107	67	95	65	79	52	54	35	38	18	29	9	15	– 1	63	27	61	34	77	34	80	43	66	57
6	104	68	83	59	85	51	61	39	43	23	45	7	21	– 4	50	30	63	31	72	34	74	51	67	55
7	101	69	89	54	90	58	63	35	42	30	48	13	22	2	47	23	65	35	63	42	58	44	69	50
8	84	64	89	59	73	55	76	39	37	24	42	17	35	3	38	20	57	35	73	39	68	37	76	48
9	90	55	95	62	74	51	53	39	44	14	53	16	41	19	26	16	37	29	48	33	60	41	66	50
10	95	62	97	65	88	48	68	36	63	26	63	23	46	15	42	12	36	29	54	33	73	33	73	45
11	93	62	90	58	92	53	68	40	66	24	62	18	40	21	54	23	42	29	73	35	63	37	84	53
12	94	66	83	56	95	59	65	39	68	28	59	23	36	25	50	25	41	25	69	42	42	34	81	59
13	100	65	75	55	91	67	49	41	54	28	55	18	34	15	44	25	48	26	54	33	47	35	75	58
14	105	66	80	51	74	55	45	35	56	32	57	30	36	8	50	21	65	26	40	33	64	38	80	62
15	86	59	84	56	79	43	48	28	62	30	59	24	38	7	47	22	69	35	53	36	53	46	77	56
16	87	54	83	58	61	47	57	33	60	32	58	24	39	11	52	24	65	33	70	29	55	44	74	56
17	80	62	94	58	71	40	57	32	54	29	48	26	55	14	57	29	61	31	67	40	51	44	72	53
18	81	55	91	60	82	43	44	32	41	29	59	26	45	16	60	32	74	35	58	36	54	43	84	57
19	74	50	85	62	80	44	42	34	57	22	47	24	42	26	64	29	73	39	63	34	59	42	82	62
20	72	45	81	64	87	42	50	27	53	31	43	34	41	27	50	33	73	44	75	38	61	38	80	53
21	85	50	85	48	91	48	61	24	47	21	42	36	44	23	50	23	69	41	69	49	62	46	88	57
22	89	54	77	54	81	51	67	29	49	26	39	30	46	19	46	23	74	41	63	35	81	54	90	61
23	86	59	84	53	86	47	68	36	49	30	47	25	46	24	45	20	76	38	62	34	72	47	92	62
24	85	58	95	54	80	55	69	33	48	28	48	25	48	30	43	21	77	35	65	36	76	47	80	63
25	89	61	92	62	70	52	66	30	54	19	47	22	55	25	47	17	77	38	75	33	72	47	80	51
26	93	58	82	63	83	53	60	34	36	23	35	27	50	24	57	28	74	39	74	39	76	43	82	62
27	79	61	86	57	66	48	55	28	27	11	33	23	49	23	66	32	53	30	75	43	82	47	82	63
28	91	52	87	56	86	43	41	31	26	1	27	10	28	23	44	28	39	26	70	50	86	56	83	62
29	95	61	95	63	91	49	42	28	13	–10	20	4	45	25	..	..	35	29	76	43	78	58	91	67
30	92	64	102	65	65	47	49	29	31	1	21	– 2	48	22	..	..	59	30	71	47	83	58	73	56
31	88	59	85	66	..	..	50	23	..	..	21	– 1	34	24	..	..	62	33	..	..	79	54	..	..
Range	62°		54°		55°		53°		78°		65°		63°		54°		52°		49°		54°		47°	
Monthly means	75°.5		72°.8		64° 6		44° 6		33°.4		30° 7		24° 9		34°.6		44° 3		51°		54. 9		65°	

TABLE "A."

The mean temperature of the several months of ten years past, 1866 to 1879, inclusive; the mean temperature of each year, and the amount of snow, rain, and melted snow, in inches.

YEAR.	DEC. '65—'76.			JANUARY, '66—'76.			FEBRUARY.			MARCH.			APRIL.			MAY.		
	Mean Temp.	Snow.	Rain.	Mean Temp.	Snow.	Rain.	Mean Temp.	Snow.	Rain.	Mean Temp	Snow.	Rain.	Mean Temp.	Snow.	Rain.	Mean Temp.	Snow.	Rain.
1866	22.20°		.75	16.40°			22.75°	6 60	6.60	29.44°	4.85	2.30	51 61°		3.19	60.20°		2.88
1867	23.31	8.60	4.65	14.49	15.10	2.70	22.90	1.60	1.84	16.91	9 50	2 12	45.65		2.80	55 27		8.25
1868	27.65	5 25	.85	11 09	8.00	.85	24 00	6 06	1.15	43.85	1 45	2.75	45.54		3 60	65.02		8.20
1869	19.35	15.50	2.10	23.38	8.00	1.30	27 51	11.25	2 45	32.55	2.25	.60	50.16	.75	2.45	60 59		6 55
1870	28.25		2.20	24.38		1.40	32.32		1.00	32 57		1.00	54.56		2.70	67.05		5 80
1871	28.05		1.00	25.02		.65	31.50		1.60	42.80		40	56.90		1.80	66.80		2.40
1872	20 04	7.03	.75	18.90	2.50	.80	29.30		.10	32.70		1.40	47.70		2 40	57 10		4 40
1873	16 08	7.10	2.10	13.13		1.60	23 09		.60	36.37		.60	45 22		15 90	59 11		19.00
1874	22 25		1 60	19.92	5.00	.65	20.09	12 35	1.55	32 15	10.25	2 51	44 65	.90	4.09	67.48		3 15
1875	25 58	4 85	.80	7.71	4.91	.38	11.56	7.75	.90	29 11	13.75	3.38	44 81		4 62	63 42		3 98
1876	32 18	.25	1.10	27.00	1 50	.06	28.25	5 75	.94	27.92	13 50	2.09	48.55	1.00	5 16	63.73		3.10
1877	16.80	1 10	.07	17.54	13.00	1.32	34.46	45	.42	32.46	6.25	1 01	49.27		5.88	59 96		7.57
1878	37.07	1 50	1.73	27.70	12.50	1 69	34.76	50	.15	46.74		3.09	53.95		4.01	57.49		5 54
1879	19.50	5.45	.65	19 27	1.25	.12	26.05	9 70	1.12	40 78	6.05	2.15	52.32		2.17	65 84		5.94

YEAR.	JUNE.			JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.		
1866	68.01		5.93	77.80		2.80	72.32		3.22	57.32°		5.65	53.08°			38 75°		1.65
1867	72.33		3.15	75 32		4 70	75.05		1.70	66.58		1.55	52.25		1.05	38 90	.75	05
1868	72.03		5.00	83.68		3.00	69.58		6 30	57.35		2 35	49.67		1 90	33.92	6.50	1.90
1869	68.70		9.05	73 30		7.50	75.19		8.00	62.00		5.20	42 07		.75	35.26		1.40
1870	74.20		2.10	82 10		2.00	69.90		3.66	66.30		6.60	53 60		2.30	42.09		
1871	76.60		2 30	76 40		14 10	74.60		3.30	62.20		1.30	53 69		1.20	34 00		3.20
1872	73.06		4.70	75 17		7.40	74.53		40	62.37		4 10	50.91		4.00	30.91		.70
1873	75.08		4 80	75.54		6 40	77 98		1.00	61 27		2.20	48.16	.50	1 60	36 95		.45
1874	74.31		18.02	82.35		1 10	78 71		1.40	64 33		11.13	54.14		2.11	34.81	2.75	1.80
1875	71.20		13.58	74.13		6.72	69.68		8.40	62.34		5.63	48 86		1 32	30.66	.50	01
1876	68.63		4.58	75 31		7 44	74.18		8.39	63.36		7.03	48.87		1.71	31.26	9.60	2 14
1877	67.45		6 41	73 45		2 20	71.75		4.56	65.44		2.37	49.68		7.11	33.96	2.10	1 70
1878	66.39		9 64	76 91		11.61	75.27		1.23	63.02		3.36	51.06	3.00	.71	41 85		.71
1879	70.51		5.05															

TABLE "B."

In the following table we have the mean temperature of the seasons and years, as also the total snow and rainfall, including melted snow.

Year.	Seasons.	Temp. of Seasons.	Temp. of Year.	Yearly Snow.	Yearly Rain and Melted Snow.	
1866	Winter	19 99°	47 53°	11 45 ins.	4.10 inches.	
	Spring.	47.03°			8.34	
	Summer.	72.78°			11.95	
	Fall.	49 75°			7.31	31.70
1867	Winter.	20.15°	46 67°	35 55	6 14	
	Spring.	39 20°			13 17	
	Summer.	74 31°			9 55	
	Fall.	52 57°			2.65	31.51
1868	Winter.	20 83°	48 84°	27.20	2 85	
	Spring.	51 53°			14 55	
	Summer.	75 13°			14 36	
	Fall.	47 00°			6 15	37.85
1869	Winter.	21 61°	47 42°	39 00	5 85	
	Spring.	47 75°			9 60	
	Summer.	72 44°			24.55	
	Fall.	45.16°			7.35	47.35
1870	Winter.	22 14°	46 61°	22 00	4 60	
	Spring.	46 17°			9 50	
	Summer.	70.00°			9.10	
	Fall.	47.64°			8 90	32.10
1871	Winter.	22 28°	46 82°	18 00	2.25	
	Spring.	49 52°			4.60	
	Summer.	71.97°			19.70	
	Fall.	42.94°			5.70	32.25
1872	Winter.	22 81°	45.69°	12 80	1.85	
	Spring.	37 80°			7.70	
	Summer.	74.22°			13 00	
	Fall.	47.71°			8 80	31.35
1873	Winter.	17 75°	47.58°	10 06	4 30	
	Spring.	46 92°			35 50	
	Summer.	76 22°			12 20	
	Fall.	48 79°			7.45	49 45
1874	Winter.	20.88°	49.81°	38 35	3 80	
	Spring.	48 13°			9 75	
	Summer.	78 50°			20 52	
	Fall.	51 13°			15.04	49 11
1875	Winter.	15 06°	45.09°	29 26	2 08	
	Spring.	45 55°			12.48	
	Summer.	71 67°			28 70	
	Fall.	47 31°			6.96	50.22
1876	Winter.	29.17°	49 20°	22.00	2.10	
	Spring.	47.77°			10 35	
	Summer.	72 89°			20 41	
	Fall.	46 73°			9.88	42.74
1877	Winter.	22 95°	47.77°	23 30	1.81	
	Spring.	47 23°			14 46	
	Summer.	70 88°			13 17	
	Fall.	49 69°			11 18	40.62
1878	Winter.	33.18°	52 64°	17 60	3 57	
	Spring.	52 73°			12 64	
	Summer.	72 85°			22 48	
	Fall.	51 98°			4 78	53.87
1879	Winter.	21 84°		22.45	1.89	
	Spring.	52 98°			10 26	

The winter season in the above table includes December, January and February. Spring, the next three, &c.

TABLE "C."

Gives the date of each day, from 1861 to 1876, inclusive, on which the mercury of the thermometer has fallen below zero, as also the degree. December being taken as the first month of the succeeding civil year. The usual sign — denoting below zero.

TABLE C.

1861	1862	1863	1864	1865	1866	1867	1868
Jan20 -20	Dec23 - 6	Jan16 -10	Nov27 - 2	Nov22 - 2	Dec 5 -10	Dec11* - 1	Nov 9 - 7
21 -24	27 - 3	Feb 2 -10	28 - 9	Dec 7 - 6	12 - 6	Jan 1 - 8	Jan 6 - 8
23 - 3	Jan 9 - 8	5 - 5	29 - 4	8 -16	13 -20	6 - 2	7 - 2
24 - 6	11 - 2		Dec14 - 4	9 - 7	14 -16	9 - 3	8 - 6
25 -13	12 -13		30 - 2	*10 -10	15 -15	21 - 3	9 - 6
27 -12	13 -12		31 -24	11 -14	16 -10	26 - 4	11 - 6
31 - 6	14 - 7		Jan 1 -23	Jan22 - 1	21 -18	27 -10	12 - 4
Feb 7 - 7	15 - 8		2 -15	24 -10	22 -30	29 - 1	15 -19
8 - 3	17 -17		3 - 5	25 -10	28 - 8	Feb 8 - 2	16 -26
	18 - 2		4 - 4	26 -10	Jan16 -15	9 -10	17 -25
	30 - 7		5 -10	27 - 7	17 -16	20 - 4	18 -13
			6 -15	28 -10	18 -13	21 -1[illegible]	20 - 8
			7 -32	Mar 2 - 5	19 - 8	23 - [illegible]	21 - 8
			8 - 6	4 6	20 -1[illegible]	24 - [illegible]	24 - 3
			9 - 8	9 -17	21 - [illegible]	Mar 2 - [illegible]	27 -16
			11 -10		24 - [illegible]	13 -[illegible]	29 -15
					Feb 4 -10	14 - 9	31 - 8
					12 -17	16 - 1	Feb [illegible] - 5
					14 -12	17 - 1	6 -12
					15 -32	24 -4	8 - 5
					16 - [illegible]		9 -22
					Mar15 -		10 -12
							11 - 3
							28 -10

*December 10th, 1865, David Jardine froze to Death.

TABLE C.—(Continued.)

1869	1870	1871	1872	1873	1874	1875	1876
Dec 8 - 9	Jan 8 - 7	Dec21 - 4	Nov29 - 6	Nov27 - 4	Dec 3 - 1	Dec28 - 3	Nov21 - 1
9 - 8	16 - 4	22 -11	Dec 3 - 6	28 - 1	20 - 7	29 -10	29 - 7
10 -14	17 - 7	23 -16	4 -12	29 - 5	Jan 4 - 3	Jan 2 - 5	Dec17 - 8
11 -30	18 -13	24 - 9	19 - 1	Dec 9 - 3	14 - 6	3 - 1	Jan10 - 2
23 - 5	Feb19 - 8	26 - 3	20 - 1	16 - 1	15 -10	4 -10	Feb 1 -12
24 - 8	20 -12	Jan13 - 9	25 - 6	20 - 5	23 - 9	5 -18	3 - 1
Jan25 - 2	Mar 8 - 2	14 - 4	26 - 4	21 -20	24 -14	6 - 8	4 - 3
Feb 4 -10	14 - 5	17 - 4	Jan23 -10	23 -20	Feb 9 - 1	8 -19	Mar20 - 4
22 - 1	15 -11	18 - 7	24 - 2	24 -16	23 - 4	9 -21	
27 - 7		Feb 9 - 7	25 - 6	25 - 3	24 - 6	10 - 9	
Mar 4 - 2		10 - 2	27 - 5	26 - 8		12 -11	
6 - 5		12 -10	28 -11	27 -10		13 -20	
15 - 4		13 - 3	31 -12	Jan 8 - 3		14 -19	
			Feb12 - 1	9 - 9		15 -10	
			13 - 6	10 14		16 - 1	
			14 - 5	16 - 8		18 - 7	
				17 -17		30 - 3	
				18 - 7		31 -10	
				24 - 7		Feb 2 - 4	
				27 - 8		3 -12	
				28 -23		4 -21	
				29 -14		6 - 6	
				31 - 7		7 - 7	
				Feb 1 -10		8 - 2	
				2 - 4		9 - 2	
				20 - 3		15 - 1	
				22 - 4		17 - 9	
				23 - 2		25 - 7	
				Mar 3 - 4		27 - 1	
						Mar 3 - 3	

In these sixteen years only twice as low as 32° and four times to 30°.

During the same period of 19 years, embraced in table "C," the mercury has risen to 100° and upwards as follows:

1857. July 15, 102°, August 5, 100°, August 13, 101°.
1859. July 14, 101°.
1860. July 15, 100°, July 20, 104°, July 24, 100°.
1861. August 3, 100°, August 4, 104°, August 5, 104°.
1866. July 23, 100°, August 6, 101°.
1868. July 18, 100°, 20, 106°, 21, 100°, 28, 101°.
1873. August 30, 101°.
1874. July 7, 102°, 8, 105°, 14, 103°, 18, 100°, 23, 104°, 24, 107°, 25, 113°, 31, 110°, August 9, 100°, 10, 111°, 19, 100°, 21, 102°.

Dr. Childs' remarks of the above last two months "that the heat was unparalleled on any record made in the United States." During this period of nineteen years eleven have passed without raising the mercury to 100 degrees.

The force or velocity of the wind is now generally rated on a scale of 10, as follows:

1. Indicates a very light breeze of 2 miles an hour.
2. Indicates a very gentle breeze of 4 miles an hour.
3. Indicates a very fresh breeze of 12 miles an hour.
4. Indicates a very strong wind of 25 miles an hour.
5. Indicates a very high wind of 35 miles an hour.
6. Indicates a gale of 45 miles an hour.
7. Indicates a very strong gale of 60 miles an hour.
8. Indicates a very violent gale of 75 miles an hour.
9. Indicates a hurricane of 90 miles an hour.
10. Indicates a most violent hurricane of 100 miles an hour.

This velocity is measured and registered by rather a costly instrument named an anemometer.

Without an anemometer, the observer notes the direction from which the wind comes, and estimates its force as 1, 2, 3, and 6. This observation and record is made three times a day—the same as with other meteorological instruments. In table "D," I give a summary of these observations for the year 1874.

TABLE "D."

Direction and force of wind for the year 1874.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Total.
Dec. 1873.......	14	2	3	9	22	7	14	25	96
Jan. 1874.......	14	6	3	5	55	11	2	39	135
February.......	21	7	5	19	17	10	7	19	105
March.	30	23	8	28	13	20	16	12	159
April............	13	30	6	58	23	8	11	19	168
May............	4	14	4	64	68	5	8	15	182
June...........	0	2	5	59	63	10	8	13	160
July............	8	6	27	26	74	15	10	6	172
August	21	6	55	37	26	7	1	4	157
September......	14	5	16	28	17	25	9	20	134
October.........	6	4	12	11	33	20	25	17	128
November......	25	2	6	5	43	22	7	31	141
Total.........	170	107	150	349	454	165	118	220	1733

By exchanging the totals of March and April, as also by transferring 50 from the total of south, to the total of north, and this gives nearly the mean of ten years past.

Tables "A," "B," "C" and "D," are all from Dr. Childs. The following table of the direction and force of the wind is taken from the report of the Signal Service. It shows how many times the wind blew from the eight cardinal points, from July, 1877, to July, 1878.

Station.	Wind	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May	June.	Spring.	Summer.	Autumn.	Winter.
Omaha.....	N.	13	14	11	31	21	22	26	33	19	18	14	12	51	39	63	81
	N. W.	13	17	12	14	23	18	22	10	18	19	19	17	56	47	49	50
	W.	3	1	4	5	2	4	6	0	6	7	7	2	20	6	11	10
	S. W.	6	3	6	3	1	6	4	1	5	8	4	4	17	13	10	11
	S.	40	24	38	18	22	24	24	23	17	8	11	21	26	85	78	71
	S. E	12	19	12	15	9	12	4	5	13	9	17	16	39	47	36	21
	E.	2	7	2	2	6	2	3	3	3	8	19	6	30	15	10	8
	N.E.	3	3	1	2	4	0	2	1	4	11	10	4	25	10	7	3
	Calm.	1	4	4	3	2	5	2	8	8	2	2	8	12	13	9	15
	Blank	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
NorthPlatte	N.	9	7	6	7	5	12	5	11	6	2	8	8	16	24	18	28
	N. W.	5	15	14	34	34	28	47	23	39	29	33	17	101	37	82	98
	W.	5	2	8	8	16	19	12	12	7	11	3	3	21	10	32	43
	S. W.	5	5	6	6	4	4	4	5	0	7	0	3	7	13	16	13
	S.	35	21	10	4	11	5	7	10	11	6	5	14	22	70	25	22
	S. E.	12	19	18	5	4	5	9	7	10	11	13	23	34	54	27	21
	E.	9	12	8	7	5	10	3	3	11	11	18	7	40	28	20	16
	N.E.	11	11	19	19	9	8	4	11	9	12	12	14	33	36	47	23
	Calm.	2	1	1	3	2	2	2	2	0	1	1	1	2	4	6	6
	Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Mean Temperature of Summer.

From the preceding tables it will be seen that the average mean temperature of the summer months, that is of June, July and August, in Eastern Nebraska, is between 72° and 74°; or, more accurately, close to 73°. At North Platte it averages slightly higher. Now, the summer isotherm of 72° starts about one-third of the distance north of the south line of New Jersey, runs northwest till it strikes the Appalachians in Pennsylvania, then goes south and west, appearing again a little south of the east edge of Ohio, and from there keeps a westerly direction until it strikes the Missouri near Sioux City. There it follows the Missouri around its big bend in Northeastern Nebraska and into Dakota Territory, until it reaches almost to the 46th parallel. From this last point it again moves a little south of west, passing through a small corner of Northwestern Nebraska, and thence on to Fort Laramie, and thence southward, mainly near to or along the foothills, until the loftier regions of Mexico are reached.

The summer isotherm of 76° is almost parallel with the last, passing through Northern Kansas, but not reaching the State line. Included between these two isotherms is a large part of Southern New Jersey, Southern Pennsylvania, the southern half of Ohio, and the greater part of Indiana and Illinois, the southern half of Iowa, and the whole of Nebraska except a very small patch in the northwestern corner of the State. Kentucky, Virginia, Maryland and Delaware are also necessarily included between these isotherms. Nebraska, therefore, has a mean summer temperature considerably higher than States in the East in the same latitudes. There are some advantages in this high summer temperature, particularly in fruit culture. It is well known, for example, that some of the finest grapes only mature where the summer temperature is from 68° to 72°. Our fine soils and natural drainage, therefore, would be without avail were it not that these conditions are complemented by a high mean summer temperature.

The Mean Winter Temperature.

The winter months are regarded as embracing December, January and February. The mean isochimal, or line of equal mean temperature of 20°, according to the Smithsonian Reports, includes the south half of the State, and the northeastern portion as far as

one hundred miles west of the Missouri. This line enters the State near its northwest corner, and then passing southeast, and then in an easterly direction, slightly north of a line half way between the Platte and the north line of the State until it reaches within about one hundred miles of the Missouri. It then makes an angle, turning to the northwest, and mainly keeping that direction until it strikes the mouth of the White Earth River. Crossing Northern Iowa, it strikes the northwest corner of Illinois, then turns northeast to Green Bay, and thence to the coast by way of the Straits of Mackinaw. From this it appears that all of Nebraska, except the small part north and west of the line just described, has an average temperature like Northern Illinois and Ohio. The portion north and west of the line described has a mean winter temperature slightly lower, if the Smithsonian data can be trusted. The number of observations, however, on which this isochimal line was based through Northern Nebraska were notoriously few and imperfect. My own conviction is that future, more perfect data will assign the whole of Northern Nebraska to at least the isochimal line of 20°.

Mean Temperature and Character of Spring.

The next season of greatest interest is that of spring. What in other words is the mean temperature of March, April and May? The best exhibit of the spring temperature is found in Dr. Childs' table, "B." From that it is seen that the mean temperature of spring for the last ten years was 47°, 47′. The reports of the Signal Offices at Omaha and North Platte do not differ materially from this determination. The Nebraska Weather Service, inaugurated first by Prof. Bailey, and now conducted by Prof. Thompson, Superintendent of Public Instruction, gives the following bulletins for the spring months confirmatory of the above, with additional facts of great importance:

Bulletin for March.—" Highest temperature recorded, 92° at Palmyra, at 2 P. M., on the 27th; lowest 21°, at Desota, on the 14th. Average noon observations for the whole State, 52°. Lowest noon temperature 15°, on the 1st. Highest noon temperature 92°, on the 27th. Average of all the observations gives the temperature of the 1st at 20°, and of the 27th at 86°. Four stations report over an inch of rainfall, viz.: Weeping Water, 1.25 of an

inch; Sterling, 1.08; Desota, 1.43; Logan Valley, 1.04. Average of all stations east of 6th principal meridian, 3/4 of an inch. West of that line, 1-10 of an inch. March, 1878, had more than three times that amount. Wild geese first seen in Cedar County on the 4th, at Kearney on the 7th. Adder's tongue in bloom at Table Rock on the 30th. Meadow larks seen at Logan Valley in Cedar County on the 23d; plover and curlew on the 25th. Prevailing winds of the month from the northwest and westerly points, but considerable also from the southeast."

S. R. Thompson, Director.

Bulletin for April, 1879:—"Highest noon temperature reported from several stations, 84°; lowest, 29°, at Logan Valley, Cedar County. Noon observations average 60°. Rainfall for all stations east of 6th principal meridian average 2 inches; west of that line 2 1/3 inches. Minden Station reports 9.93 inches. As there may be some mistake about this, it is not included in the averages. Rainfall of April, '79, almost the same as April '78 It seemed drier this year because at the beginning of April, 1878, the ground was very moist, while in 1879 it was comparatively dry. Prevailing winds from southeast. Plums in bloom on the 10th, in the north part of the State; peaches on 19th; apple trees on 23d. Box elders in leaf on 28th. Vegetation several weeks later than last year."

S. R. Thompson, Director.

Bulletin for June, 1879:—Temperature—The highest noon temperature was 100°, reported at Humboldt, Richardson County.

The highest at no station was less than 87°; generally it was above 90°.

The lowest was 50° reported from Weeping Water. The general report averaged about 60° for the lowest noon observation.

Light frost on the night of the 1st, at Inavale, Webster County, also at Kearney on night of the 2d.

Rainfall—During first ten days of the month the rainfall was very slight; from many stations none at all are reported. During the two last decades—ten days—the rainfall was abundant and evenly distributed. The average of all stations reported east of the sixth principal meridian is 4.88 inches, and for all west of that line 5.46 inches. The greatest fall reported at any one station east was at Mission Creek, Pawnee County, being 8.25 inches, and the smallest amount reported was at Palmyra, Otoe County, it being

3.07. The largest fall reported west was at Minden, Kearney County, which was 10.30 inches, and the smallest fall was near Genoa, Platte County, it being 3.25 inches. The average for the State was just 5 inches.

Prevailing winds were from the south and southeast.

June 10th a severe storm reported from Inavale; high wind with hail and rain; injuring crops and destroying buildings. Storm of June 25th was severe in many parts of the State, the wind doing some damage to buildings and beating down the corn.

Crops—General reports very encouraging. Wheat damaged in some localities by chinch bugs. S. R. Thompson, Director.

From the preceding bulletins the general character of the spring months can be determined. March is often characterized, as elsewhere, by frequently changing winds and sudden rises and falls of temperature. Pleasant weather sets in in April. The genial sunshine and the bursting into life of the vegetable kingdom in this stimulating climate renders this a most inspiring season.

Autumns.

Nothing in the Nebraska climate is more notable than its peculiar, long, mild, dry autumns. It can be seen from Dr. Childs' exhibit that the average temperature for the ten years ending with 1875, for September was 62° 20′, and for October 50° 64′, and for November 35° 61′. The average for the entire three months for the ten years ending in 1875 is 49° 49′. The signal service reports the temperature at Omaha for September, 1878, as 66° 6′, and for October, 51° 1′, and at North Platte for the same year, for September, 64° 6′, and for October 44° 6′. It will also be observed that excessive rains seldom fall during these months. The autumns are therefore exceedingly mild and long. Sometimes there is a short rough spell in October, but almost universally it is followed by mild weather which is often prolonged into December, and has been known to last till January. These long "Indian Summers" are here, even more than elsewhere characterized by a curious haze which mellows the light of the sun. It has the curious effect on "high strung" natures of rousing the poetic sensibilities, and giving the weird shadowy experiences of dream land. It is a most favorable season for toil, mental and physical. The numberless things to be done on the farm become, during this season, almost a pastime to the agriculturist. Existence to a healthy body now is a pleasure and toil a delight.

Mean Temperature of the Whole Year.

The mean temperature of the whole year in Nebraska, notwithstanding the extreme cold of winter, is remarkably high. The mean yearly isotherm of55°, for example, which passes through Washington, D. C., Cincinnati, and southern Iowa, strikes the Missouri River a little south of Nebraska City, and then moving a little north of west crosses the Platte near Columbus, and thence in a northwesterly direction across the State. This mean annual isotherm therefore embraces over one-half of the State. The mean yearly isotherm of 52½° which passes through Pittsburgh, Pennsylvania, crossing the centre of Iowa diagonally, strikes the Missouri River above Sioux City, thence following the river for some distance takes in the whole of Nebraska not included in the yearly isotherm of 55°. The yearly isotherm of 57½° passes south of Nebraska. A portion of southern and southwestern Nebraska is therefore included between the yearly isotherms of 57½° and 55° and the balance between 55° and 52½°.

Extremes of Temperature.

In Dr. Childs' record (Table) ofnineteen years the mercury rose to 100° F., and upwards, twenty-nine times, or on an average a little more than a day and a half a year. The hottest year was that of 1874, when in July and August, the thermometer rose to 100° and upwards on twelve different days. On July 13th it rose to 113°, it being the hottest day according to Dr. Childs' record, in nineteen years.

In table C, it will be seen how many days during the time from 1861 to 1876, the mercury fell below zero. It will also be seen from this record that while the mean temperature of Nebraska is high for a region in these latitudes, its extremes are great. And yet no acute suffering or other ill consequences flow from it. As we will hereafter see, the heat of summer is modified by the breezes that fan the land. On the other hand, the severe cold of the extreme days of winter are made endurable by the dryness of the atmosphere. The dryness is so great and potent that the cold is not felt here more when the thermometer marks twenty degrees below than it is in Pennsylvania when only at zero. The reason of this is well understood. It is moisture that intensifies the sensation of chilliness. Every one knows the meaning of a drizzly, chilly day. It is because the atmosphere in the east is more filled with moisture

that makes the sensation and effect of cold so much more severe there than here. It is owing to this fact also that a temperature which is fatal to fruit buds in the east has no effect on them here.

THE WINDS OF NEBRASKA.

The atmosphere is rarely quiescent in Nebraska. While hurricanes are very rare, storms are more frequent in winter, and gentle zephyrs and winds are almost constant. These greatly modify the heat of summer and the cold of winter. When the thermometer is up among the nineties, even a south or southwest wind makes the weather endurable. At this high temperature the atmosphere is almost certain to be in perceptible motion from some direction. By reference to table D of Dr. Childs' and the report of the U. S. Signal Office on winds, it will be seen that the prevailing winds in the winter are from the north and northwest. With the coming of Spring there is a great change in this respect. The winds veer around and a strong current sets in from the south, blowing from the Gulf of Mexico, but entering the interior is deflected by the earth's motion and becomes a southwest wind. This remains the prevailing wind during the whole of summer, and often until late in autumn. It sometimes happens that this southwest wind commences to blow during the coldest days of winter, when the curious phenomenon is observed of snow melting when the thermometer is at, a little above, or even below zero. This of course is caused by the temperature of the coming current of air being much higher than that of the place. This character of north and northwest winds in winter, and south and southwest winds in summer, with some local exceptions is the dominant character of the atmospheric movements between the Mississippi and the mountains, and the gulf to an unknown distance north.

THE STORMS OF WINTER.

From no cause has Nebraska, in company with Iowa and Kansas suffered more in popular estimation than from the reputed severity and frequency of its storms. And yet they occur at comparatively long intervals. During one-half the years none are experienced of any severity, and when they do come the laws that govern their occurrence are so well understood by at least the older citizens of the State that little damage is suffered from them. One of the laws of their occurrence is their periodicity. When the first one of the season comes whether it is

in November, December or January, a similar one is almost sure to occur within a few days of a month from the first. Those whose necessities therefore or business calls them out during the winter season need only note the date of the first to know when to guard against the next. It is rare, however, that more than one of these periodical storms is of great severity.

When the storms commence they are rarely heralded by anything except areas of low barometer. Even this warning is sometimes absent. The wind generally blows gently at first from the north, northeast or northwest. It is often preceded and accompanied by a fall of fine snow. Sometimes the storm of wind does not commence till the snowfall has ceased. The wind gradually increases in intensity, accompanied by a falling thermometer. Its violence increases until the snow is blown into huge drifts, and sometimes all that fell during several days seems mingled with the atmosphere, so that it is impossible to recognize roads, or even the points of the compass. Progression becomes impossible except in the same direction with the wind. This is an extreme case, but a truthful one, and fortunately of rare occurrence. Such storms last from one to three days, and a few instances are on record where they have lasted five days. When the wind ceases to blow the thermometer reaches its lowest point, and the intensest cold that occurs in these latitudes is experienced. In a few days the thermometer rises, the weather becomes moderate and pleasant, and all about the storm is apt to be forgotten. So mild does the weather often become in December and January between these storms, that men work in the open air in their shirt-sleeves. This is what often deceives the unwary, and especially new comers. I have known men, starting off in new settlements for loads of wood, going in their shirt-sleeves with a single coat in reserve in the wagon, to be caught in such storms, and losing their way, to perish. Proper observation and care as we have seen would avoid such suffering and disaster. Notwithstanding, however, these storms of winter, there are many more days here during winter when men can work comfortably in the open air than in the East.

Clearness and Purity of the Atmosphere.

A number of circumstances combine to make the atmosphere of Nebraska exceptionally pure and clear. Its mean elevation of 2,312 feet above the sea, its general slope towards the east and

south, its distance from the sea, the constant motion of its atmosphere, the general character of its finely silicious soil and perfect natural drainage, and its general freedom from swamps, bogs and sloughs, all combine to give the State the purest possible atmosphere. Its constant breezes sweep away or mingle with the general current of the atmosphere such impurities as may have been generated from any cause. Only during the Indian summer of autumn is there a haze that obscures distant objects. Fogs seldom occur. It is remarkable at how great a distance objects can usually be seen. Often when a bluff is ascended the larger limbs of a tree can be counted from eight to twelve miles distant. Objects universally appear to be much nearer than they really are, to strangers coming from the East. I have sometimes been amused to see them going through the same experience that befell me during my first residence here—the experience of shooting at prairie chickens when they were a quarter of a mile off, under the supposition that they were close by. Only gradually does the eye get accustomed to measure distances in such a clear and rare atmosphere. In fact, judging from the European meteorological reports, the atmosphere of Nebraska is as clear, and much purer, than the far-famed skies of Italy and Greece.

Owing to this pureness of the atmosphere, clouds, when formed, are exceptionally clearly out lined. They stand out as most conspicuous objects in the sky. Nothing can surpass their evening or morning splendors. The sunsets are remarkable for the brightness and variety of their coloring. I have seen many magnificent sunsets in the mountains, but never anything to compare for extent, coloring, form and grandeur, with those that so often occur on the rolling prairies of Nebraska.

Another prominent feature of the Nebraska atmosphere is the allotropic form, called ozone, that oxygen so constantly assumes. The amount of this in the atmosphere is very much greater than in the East. During 1869 and 1870, while engaged almost constantly in traveling and exploring over Northern Nebraska, I carried with me much of the time the so-called Shoenbein test papers.* These turned blue in a short time when exposed, thus indicating the presence of ozone in the atmosphere. This rarely occurs in the East, and even but slightly after a thunder-storm. Many other

*Paper moistened with a solution of potassium iodide and starch, and kept until wanted for use, in a tightly-stoppered bottle.

experiments were made, all indicating that the atmosphere was exceptionally rich in ozone.

The cause of this condition of our atmosphere is probably two-fold. First, it is due to the comparative dryness of the atmosphere. Second, it also results from the highly electric condition of the atmosphere. The greater the elevation, other things being equal, the more abundant is the electricity (Tyndall). A friction electric machine can be charged here on almost any day in the year with ease. In the East during much of the time this cannot be done. Now, one of the most potent of all agencies for the formation of ozone is the silent discharge of electricity through oxygen, or through the atmosphere which is in part composed of oxygen (Barker). In fact, as Barker has shown in practice, there is no agent so efficient for the formation of ozone as Siemer's Tube, through which there is a constant silent discharge of electricity from a Ruhmkorff coil. Now, through our dry atmosphere, there is a constant electric discharge, which generates ozone in immense quantities. The bearing of ozone on the question of health will be considered under another head.

CHAPTER III.

CLIMATE CONTINUED.

Moisture and Rainfall.

Abundance of Moisture—The Rainy Season—Decrease Towards the West —Vapor in the Atmosphere—Rain Charts and their Explanation—Exceptional Conditions of Rainfall in the Niobrara Region and its Cause—Comparative Estimates with Europe.

EASTERN Nebraska has an abundance of moisture. This may appear like an exaggeration to those who were educated to believethat Nebraska was an arid region. And yet there is nothing in the natural history of the State better established than that there is here an abundance of rainfall.

When the snows of winter disappear the ground is in good condition to be worked. Sufficient showers come during early spring to excite the crops of cereal grains, grasses and corn to an active growth. Sometimes it is comparatively dry between the spring showers and the June rains. These come sometimes earlier than June—in the last of May, and sometimes not till the last of June and constitute the rainy season for the State. It begins whenever the "big rise" of the Missouri and the Platte occur. This rainy season lasts from four to eight weeks. In fifteen years I have not known it to fail. During its continuance it does not indeed rain every day, except occasionally for a short period. Generally during this period it rains from two to three times a week. It is more apt to rain every night than every day. In fact during the whole of this season three-fourths of the rain falls at night. It is not an unusual occurrence for rain to fall every night for weeks, followed by cloudless days. This rainy season of June occurs at a period when crops most need rain, and owing to the regularity of its occurrence, drouths sufficiently severe to destroy the crops in eastern Nebraska, where there is proper cultivation, have not yet been known. Even in 1874, when the drouth in some parts of the State was damaging, there were some fields of corn that produced

good crops where the majority were failures. The successful fields were the ones that were well and deeply cultivated. After the wet season of June, which sometimes extends into July, is over, there are rains and showers at longer intervals until and during autumn. During winter it rarely rains. Snow falls in winter, but seldom to a great depth. The snows generally range in depth from one to ten inches and in a few extreme cases to fifteen inches. During the majority of winters, as can be seen from Dr. Childs' table A, no snows fall over eight inches in depth.

West of the 100th meridian the amount of rainfall gradually decreases from the yearly average of thirty inches, at or near Kearney Junction to twenty inches at North Platte. If the last two years only were taken into the account, even there and almost to the west line of the State the rainfall would be estimated at thirty inches. It will hardly as yet average that much for ten years, though for reasons stated hereafter there will be that amount of rainfall over western Nebraska in the near future.

Even the relative amount of moisture in the atmosphere is high. This is evident from the reports of the Signal Service at Omaha and North Platte. It reports as much vapor on an average in the atmosphere at Omaha as exists in the States in the Mississippi Valley. At North Platte which represents western Nebraska, the atmosphere contains a comparatively large amount of vapor. The following table, taken from the report of the Signal office for the year ending June 30th, 1878, gives the vapor in the atmosphere for each month.

Monthly and annual mean relative humidity; from observations taken at 7 a. m., 2 and 9 p. m., &c.

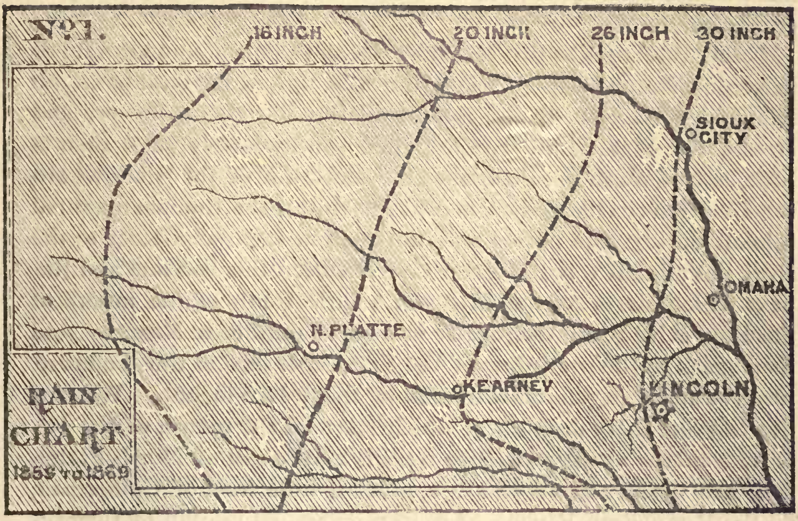
	N. Platte.	Omaha.
	Pr Cent.	Pr Cent.
July, 1877	47.2	62.4
August, 1877	57.5	*a*67.4
September, 1877	52.9	69.0
October, 1877	64.8	73.6
November, 1877	64.3	73.7
December, 1877	68.4	77.8
January, 1878	68.4	78.6
February, 1878	66.3	73.1
March, 1878	61.4	64.8
April, 1878	54.5	59.8
May, 1878	64.4	63.6
June, 1878	69.7	71.1
Annual Means	61.6	69.6

In addition to the preceding table it may be repeated here, that according to Dr. Childs' tables the amount of rainfall during the year ending November 30th, 1877, was 40.62 inches; for the year ending November 30th, 1878, was 53.87 inches. The average for the ten years ending November 30th, 1878, was 42.86 inches.

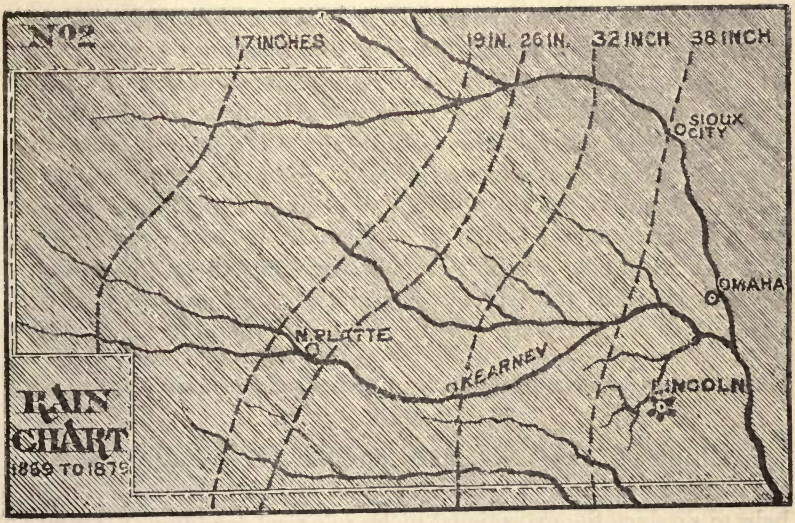
In order to exhibit the areas of certain quantities of rainfall to the eye, I have constructed the following rain charts for the State. The first chart gives the average rainfall during the ten years ending November 30th, 1868. The second gives the average rainfall for the ten years ending November 30th, 1878. In constructing these charts I have availed myself of all the Smithsonian Reports, the Signal Office Reports, and my own observations of fifteen years. It will be seen that my results are very different from those hitherto obtained by an exclusive dependence on the Smithsonian Reports. By comparing these two maps it will be seen that there is a constant increase of rainfall in the State.

Chart No. 1.—This chart gives the areas where a certain average amount of rainfall occurred from 1859 to 1869. The rainfall during the years nearest to 1859 had less, and the years nearest to 1869 had more than that indicated on the chart. In other words, the amount of rainfall towards 1869 approximated already closely to that of the next period. These facts, however, cannot be exhibited on the diagram.

From the Missouri River in Eastern Nebraska to a line running across the State from north to south, from above Dakota City and near to Sioux City on the Iowa side, the average rainfall during these ten years was thirty inches. From this line to another that starts near the mouth of the Bow River in Cedar County, and which runs a little west of south to near Kearney Junction, and then southeasterly to a point on the State line half way between the Blue and Republican rivers, the rainfall for the same time was twenty-six inches. The next line west of this starts a little above the mouth of the Niobrara, and crosses the State diagonally to a point a little east of North Platte. The space enclosed between this line and the preceding received a rainfall during this period that averaged twenty inches. The next line west of the last starts about longitude 101°, runs southwest until it strikes the Niobrara, and then southerly until it reaches the south line of the State opposite Big Springs. An average yearly rainfall of sixteen inches fell here during this same period. West of this line the average rain-



ANNUAL AVERRGE RAINFALL FROM 1859 TO 1869.



ANNUAL AVERAGE RAINFALL FROM 1869 TO 1879

fall was not determined, but it could not differ much from the preceding space.

Chart No. 2.—On this chart we have the mean annual rainfall between 1869 and 1879. Along the Missouri, as far west as to the line which starts near the mouth of the Big Sioux River, and crosses the State southerly and then southwesterly, and then a little east of south until it strikes the south line of the State where the Blue River emerges from it, over this space the mean annual rainfall during this period was thirty-eight inches. Closer to the river the rainfall was still greater. Between this last line and the next which starts on the Missouri a little south of the mouth of the Bow River, runs diagonally in a curve until near Kearney, and then south to the south line of the State, this section thus bounded receives an average annual rainfall of thirty-two inches. West of this last line there is another, which starts at the mouth of the Niobrara, curves southwesterly to a point a little east of North Platte, and then slightly southwest to a point a little west of Culbertson, on the Republican River. An average annual rainfall of twenty-six inches covers the space bounded by these lines. The next line west commences on the north line of the State at the mouth of the Keya Paha, runs southwest across the State, striking the south line half way between Culbertson and the west line of the State. The space between this line and the last receives an average annual rainfall of nineteen inches. Between this line and the next west, which starts a little east of the 101° meridian, runs in a curve southwesterly to a point near Lodge Pole, on the Union Pacific Railroad, and then south to the south line of the State. The space bounded by this and the last line receives an average annual rainfall of seventeen inches. West of this line the rainfall is not definitely determined, but it probably does not differ materially from the preceding section. It should be remembered in examining these charts, that towards each line the amount of rainfall shades into the next division.

Exceptional Meteorological Conditions in the Niobrara Region.

In Chapter I., some exceptional physical features were noted in the Niobrara region. These exceptional physical features no doubt help to produce the exceptional meteorological conditions. Of late years more than formerly, in these sections during June, July and

August, there are almost daily thunder-showers. There is little snowfall in winter, but when the hot weather approaches these storms are almost constant. Every time it has been my fortune to be there, every day there was a thunder-storm, and on some days several. The morning sun would appear with wonderful clearness, and the heat would become intense by two o'clock, and then in a few minutes clouds would form and thunder peal. After the outpouring of the clouds, which generally lasted from thirty minutes to an hour, the clouds would vanish and the sun appear. Frequently there was another thunder-shower during the early hours of the night.

The cause of these frequent showers appears to me to be this: At the head of the Elkhorn and the Loups, and between these rivers and the Niobrara, there are great numbers of small lakes and ponds and sloughs. These are underlaid by an impervious clayey stratum, so that the only escape possible for the waters is by overflow and evaporation. Some drain into these rivers, but many have no visible outlet. Near to and among these lakes are the Sand Hills, already described. The sun shining on these hills heats them up to an extreme degree, and necessarily also the atmosphere around and above them. I have experienced a temperature myself here in the shade of 110° F., when the register at Plattsmouth marked only from 85° to 90° F. The consequence is, that the evaporation is enormous. The atmosphere becomes supersaturated with moisture. The least fall now in temperature, produced by a change of wind or other cause, creates cloud, the play of lightning and rainfall. My own experience in this region is not a solitary one. Captain W. S. Stanton, of the Topographical Engineers of the U. S. A., had a similar experience. The "cattle men" who have invaded that region testify to the same facts. This region of showers covers the entire section occupied by both lakes, sloughs, ponds, and sand hills. With the increasing moisture all over the State, it will be interesting to note the changes as the Sand Hills become more covered with grasses. The rainfall there will then probably continue to increase, but will be more equally distributed.

Comparative Estimates with other Regions—Europe:—While therefore many will admit that there is an abundance of rainfall east of the 100th meridian, they still claim that west of that line it is too dry for the successful production of anything but stock.

They point to the less amount of rainfall west of that line, and ask how a region that receives so little can be utilized for agricultural purposes. Two replies can be made.

The fallacy of this conclusion can be seen at once if we compare the rainfall in western Nebraska with that which obtains in some of the most favored spots of the old world. The following table I have taken from Guoyot:

Table of Rainfall.

	Depth in Inches
British Islands,	32
Western France,	25
Eastern "	22
Sweden,	21
Central and North Germany,	20
Hungary,	17
Eastern Russia, Kasson,	14
Northeast Portugal	11
Madrid	10

Paris itself, according to the researches of Arago, has only an average annual rainfall of twenty inches. (Cosmos, vol. 1, p. 331.)*

Now it is true that there are many rainy days in western France (152) and in central and north Germany (150) yet if we count in the nights when it rains and the days and nights when it snows, there is not so much difference as at first imagined between the wet days of Nebraska and middle and western Europe. Regions in Europe with less rainfall than even western Nebraska, are made successful in agriculture. Less toil than is expended to make the dry portions of Europe a garden would make western Nebraska agriculturally rich. Even, therefore, judged by European standards, western Nebraska is already sufficiently watered for the needs of certain kinds of agriculture.

Not only is western Nebraska far removed from desert conditions, but every part of North America. No sections of its low or table lands have the aridity that Humboldt and Ehrenberg found [Cosmos] between the valleys of the Irtish and the Oby. There with temperature of 74° 7′ the dew point was at 24°. The air therefore contained only .10 of aqueous vapor. The structure of North America makes *genuine* desert conditions impossible. There are dry and arid sections but the aridity nowhere produces a genuine desert comparable to the Sahara.

* See also for early rainfall in Central Europe, Gasparins' Researches.

The second reply to those who object to the little rainfall in western Nebraska, is that the rainfall is increasing from year to year. This fact will be considered in the next chapter.

CHAPTER IV.

EVIDENCES OF INCREASING RAINFALL IN NEBRASKA—SOURCES OF RAINFALL.

Appearance of New Springs—Increasing Size of Streams—Changing Vegetation—Former Character of Vegetation—Causes Producing Increased Rainfall—Wrong Reasons Assigned—True Reason, the Increased Absorptive Power of the Soil, produced by Cultivation—Experimental Proofs—Special Absorptive Power of Nebraska Soil—Extension of Sufficient Rainfall over Western Nebraska—Original Sources of Rainfall—Effect of Change in the Direction of the Winds—Moisture from the Rivers—Amount of River Surface Exposed to Evaporation—Temperature of the Rivers—Nebraska effected by the Amount of Precipitation in the Mountains.

SOON after I first came to the State in 1864, it was reported that some new springs had made their appearance at the base of the bluffs facing the Missouri bottom and river in Dakota County. On investigation this was found to be correct. This phenomenon was observed in other portions of the State. It has occurred, for example, during the last few years in the Pierce precinct in Lancaster County. Up to this time I have a record of one hundred and fifty springs that have made their appearance during the last ten years where they were never known before. This same appearing of new springs has been noticed by many observers in the State, and is particularly familiar to the older settlers of the State. Connected with this same line of facts is the phenomenon of the appearance of water in old creek beds, where it apparently had not been flowing for ages. Many of the smaller tributaries of the Elkhorn, the Logan, the Bows, the Loups and the Niobrara, with beautiful small bottoms and old stream beds in the midst or one side of them, and which were perfectly dry when I first knew them in 1865 and 1866, are again living streams. Indeed many of them, especially towards the head of the Elkhorns, that had sod grown over the stream beds which were even difficult to find so nearly obliterated

were they, are again supplied with water, not merely during part of the year, but apparently permanently.

Still another fact in the same connection is the increasing size of the streams of the State. Old settlers observe this. It is a phenomenon that every old settler must notice, who has been interested in matters of this kind.

The changing vegetation of the State proves the same fact. There was a time within the memory of many now living when the buffalo grass was the most conspicuous vegetable form west of the Missouri. When Lewis and Clarke passed up the Missouri in 1804, it was almost the only grass that they found growing along this portion of their route. Fremont observed the same thing as late as 1842. The first settlers in this territory found it abounding along all the river counties. The early freighters across the plains depended most on it for pasturage for their cattle. Now how changed. It has almost entirely disappeared for two hundred miles west of the Missouri. There is comparatively little of it now on the third hundred. Every year it is retreating further westward. Its place is supplied with grasses indigenous to moister climates. Where formerly the ground was covered with grasses from two to four inches high, there is now a carpet of green from six inches to four feet high. Many of the blue joints and sorghum grasses exceed even this height. Still other forms besides the grasses, characteristic of moist regions, are occupying the spaces left by the retreating buffalo grass. There is also an increase in the spontaneous growth of timber. Wherever there are abandoned cultivated fields, and the prairie fires are kept away, and the tract is left unmolested from other hindering causes, thick growths of cottonwood and sometimes box elder frequently, soon monopolize the ground. This is especially true of lands in close proximity to existing timber belts. There is an increasing disposition to do this all over eastern Nebraska. Where formerly there was not sufficient moisture to start the seeds into life on the high lands, which are scattered each year by the winds, birds and rodents, there is an abundance. In fact it is questionable, if prairie fires were entirely repressed, whether groves of timber would not now gradually creep over all the unoccupied lands of Nebraska. The proofs, therefore, that the rainfall of Nebraska is steadily increasing, are manifold. If space permitted, many more could be given. It is therefore probable that the early explorers of this region were cor-

rect in ascribing to it a partially desert character. And yet even then they could only have been partially correct. No desert can support countless thousands of buffalo, elk, deer and antelope as the plains of Nebraska did when Lewis and Clarke made their first voyages of discovery up the Missouri. The probabilities are, that those eminent explorers confounded the appearance of a section closely pastured, and in some places made bare by the pasturing, of those immense herds of buffalo of which they speak, with the barrenness that a true desert always exhibits. A land that is supplied with sufficient moisture in such a climate as this, to produce food for such an affluence of animal life, can always be made available for the purposes of a high civilization.

Causes that are Producing Increased Rainfall.

Various reasons have been assigned to account for the increased rainfall of the State. Some have maintained that the cause is secular —that there are great periods when the moisture of a region increases for ages independent of any human agency, and that when it has reached a maximum it commences to decrease, which continues until it reaches a minimum. According to this theory, this region is now in a stage of increasing moisture. The advocates of this theory point out the fact that the Great Salt Lake in Utah, and Lake Mono, lying at the eastern foot of the Sierras, are both undoubtedly rising.* One of the objections to this theory is that the geological causes which produce increased rainfall, are not now spontaneously operative. Western America passed through many such revolutions during the progress of the later geological ages, and their causes are well understood. When, for example, the region of the plains was much lower than at present, and were dotted over with great fresh water lakes, a much moister climate than the present must have prevailed. The country between this and the Pacific is not now sinking—it is rather rising at the rate, according to Whitney, of a foot or two to the century. Denudation keeps it at about the same level. Unless therefore the cause is extra terrestrial we cannot ascribe the increasing rainfall to merely secular changes. There are no cosmical causes definitely known that would cause an increase of rainfall over an isolated region of the earth. That cause, therefore, as a producer of increased rainfall must also be dismissed.

*On Lake Mono see LeCutes' paper on the existence of volcanoes around Mono, read before National Academy, April 18th, 1879.

Another theory tenaciously held by some, is that the increased rainfall is produced by the iron on the railroad lines of the State and the wires of the telegraph lines. A few also believe that it is effected by the disturbance of the atmospheric circulation through the concussions of locomotives and moving trains. The objection to these views comes largely from the fact that in the older States where railroad lines are much more numerous and have existed much longer, no increase of rainfall has been noticed.

A more plausible theory is, that the planting of trees has been the cause of increased rainfall. This, I admit, is a helping cause, but cannot be the main cause of increased rainfall. In Nebraska increase of rainfall commenced before the number of trees planted equaled the number destroyed. Comparatively few of the first settlers planted trees. Again, the statistics of forestry in the east, in Europe, in Asia, show that forests modify temperature, the violence of winds and equalize rainfall, but do not increase it. While therefore it is admitted that the growth of forests exercises the happiest influences on climate, it is still evident that we must look elsewhere for the permanent causes of increasing rainfall. The same argument that applies to forests can be used in reply to those who insist that increased rainfall is due to the productions of corn and the cereal grains. It may be that the *continued and combined* action of these causes has some effect in increasing rainfall, but it must be small. There is, however, an other cause, not heretefore mentioned, most potently acting to produce all the changes in rainfall that the facts indicate have taken place. What then is that cause?

It is the great increase in the absorptive power of the soil, wrought by cultivation, that has caused, and continues to cause an increasing rainfall in the State.

Any one who examines a piece of raw prairie closely, must observe how compact it is. Every one who opens up a new farm, soon finds that it requires an extra force to break it. There is nothing extraordinary about this. For vast ages the prairies have been pelted by the elements and trodden by millions of buffalo and other wild animals, until the naturally rich soil became as compact as a floor. When rain falls on a primitive soil of this character, the greater part runs off into the canyons, creeks and rivers, and is soon through the Missouri on its way to the Gulf. Observe now the change which cultivation makes. After the soil is broken, the rain as it falls is

absorbed by the soil like a huge sponge. The soil gives this absorbed moisture slowly back to the atmosphere by evaporation. Thus year by year as cultivation of the soil is extended, more of the rain that falls is absorbed and retained to be given off by evaporation, or to produce springs. This, of course, must give increasing moisture and rainfall.

In order to test the accuracy of this theory, which struck me as the only true explanation of this phenomenon as early as 1867, I, at various times, made some experiments. The first accurate experiments I made in May, 1872. I went east of the Antelope, about a mile, from Lincoln, to a farm now owned by Mr. Hawley, after a heavy rain. With a rule, six inches square was marked off, of unbroken prairie, and this was taken up six inches deep and placed in a porcelain dish that had been previously weighed. The same amount to the same depth, was taken from a cultivated field. The difference in weights between the two specimens was sufficiently great to prove that the cultivated land absorbed at least during this rain, twelve times as much moisture as the uncultivated. The specimens were taken from lands only a few yards apart. After another rain, from near the same locality, a square foot three inches deep, was lifted and compared with an equal amount from an adjoining field. The specimens were first weighed, then dried and then weighed again. The difference in this case indicated that ten times as much moisture had been absorbed by the cultivated ground as by the unbroken prairie. In June, 1873, similar experiments were made and with the same results. Where the rainfall is slight, the difference will not be found to be so great. Much also depends on the lay of the land; care must also be taken that the cultivated land that is experimented with, lies adjoining unbroken prairie, as there is often considerable difference in rainfall, especially in thunder storms, in the space of a quarter of a mile. In all cases the experiments were made immediately after or during the intermissions of rainfall. After only slight rains, the difference in absorptive power was only as four to one. The mean, however, of fifty of these experiments, gives an average absorptive power of cultivated ground over unbroken prairie of nine to one. To make allowances, however, for possible mistakes, I will make eight to one the basis of our future calculations on this subject.

When the first settlements were commenced in Nebraska the rainfall of the State was not over twenty inches. Of these twenty

inches probably not more than five inches soaked into the ground. Cultivated soil, however, absorbs nearly all the rain that falls. Where thirty-two inches of rain now falls in Nebraska on cultivated ground, not less than twenty-four inches are absorbed by the soil. Some of this is slowly given back into the atmosphere, and some of it goes to form the new springs of water that are making their appearance in so many places. Any one can see that this must make an enormous difference in the moisture of the atmosphere and on rainfall. Before the settlement of the State, and before the consequent cultivation of the soil, what rain did fall, as already stated, soon left the State through creeks and rivers. Now the greater part of what does fall on all cultivated or broken ground, is retained by the soil which becomes a reservoir of water to supply growing crops, and to give greater humidity to the atmosphere.

Absorptive Power of Nebraska Soil.

No soil in the Eastern States has so great an absorptive power as the land in Nebraska. There, as a general rule, the underlying hard rock is soon reached, and during excessive rains the thin soil is so supersaturated with water that excessive denudation of the soil is common. A thin soil also dries out, because there are no stores of moisture below from which it can draw supplies. Here, however, the superficial deposits are of very great thickness. The loess itself, ranges from two feet to two hundred feet, and often where it is thin, there are below it great bodies of drift. The average thickness of all the superficial deposits—loess and drift—is considerably over one hundred feet. This thickness, therefore, of surface materials constitutes the huge sponge that absorbs excesses of rainfall, and retains it to be given back to the atmosphere only gradually.

Here, then, we have a cause competent to account for the increased rainfall of the State—a cause that not only has operated thus far but is continuous. Through the operations of this cause, the rainfall will become even more abundant than it has yet been, especially over the central and western portion of the State. The area of cultivation is extending rapidly each year, and continual encroachments are made on the lands in western Nebraska, that have been condemned as barren because of a deficiency of rainfall. Last year a large amount of land breaking was done near to and west of the 100th meridian in the Republican Valley and the table lands

adjoining it. And it is a remarkable fact, that last winter, (1879), there was an exceptionally large fall of snow, and this summer an abundant rainfall in the same region. In fact, this snow and rainfall extended all over Western Nebraska.

The question is often asked whether the causes now producing the increased rainfall over the eastern two-thirds of the State will ever be sufficiently operative over the extreme western third as to make it an agricultural region. Of this I have no doubt. It probably will take a longer time to produce this change here than it did in eastern Nebraska. The cause of this will be discussed presently. When the great body of the land near to and west of the 100th meridian is once cultivated that is capable of cultivation, the sufficiently and increasingly moist region will encroach gradually on the dry region until it is entirely crowded out of the State. And the reason why this cause will be slower here in its operation is because extreme western Nebraska is under the lee of the Rocky Mountains. The moisture-bearing winds do not strike it so directly as they do eastern Nebraska. This is better understood when

The Original Sources of the Rainfall of Nebraska are Considered.

These sources are mainly of a two-fold and combined character. One source is the moisture-laden winds from the Gulf of Mexico; the other is the enormous evaporation from those rivers of Nebraska that have their source in the Rocky Mountains.

Rains are most apt to fall when there is a change in the direction of the winds. If the wind, for example, has been blowing for days from the southwest, south, or southeast, and turns around and comes from the north, rain is almost certain to fall. There will also be a fall of rain if the change is from the north to the south. Any one looking at a map of the United States will see that the south wind coming directly upon the west end of the Mexican Gulf, would strike Red Willow, Furnas, Dawson, Custer, Elkhorn, and Knox counties. Whenever, therefore, all of Nebraska, including these and the counties east of them are bathed by this moisture-bearing wind from the Gulf, either after a north wind or followed by one there is precipitation of moisture into cloud and generally rainfall. When the wind is slightly from the southeast, extreme western Nebraska shares in this rainfall, otherwise it does so to only a limited extent. This is, it appears to me, one reason

why there has been less rainfall in this section than in eastern Nebraska.

As, however, there are trusty indications of a regular rate of increase of rainfall for western Nebraska, similar to that going on in eastern Nebraska the probabilities are that when the eastern two-thirds of the State are once properly cultivated, and its rainfall averages forty inches, that of western Nebraska will approximate twenty-eight or thirty inches, and that in this State is sufficient to produce successfully the cereal grains, cultivated grasses and corn.

The second source of rainfall for Nebraska is *the moisture from the rivers that flow from the mountains.* These rivers are the Platte, the Niobrara to a small extent, and the Missouri and its tributaries. The flood time of these rivers is always a rainy season for Nebraska. This rainy season comes earlier or later as the "big rise" is earlier or later. Then the moisture that is wafted here by the winds from the Gulf, is reinforced by the moisture that is evaporated from these rivers; and the consequent precipitation into cloud and rainfall, constitutes the rainy season for Nebraska. A map of Nebraska shows how two of these rivers run the whole length of the State, and that the mighty Missouri is east and north of it. The Missouri too, it should be remembered, has a course of four hundred miles along eastern Nebraska, for though the State is little more than two hundred miles from north to south, the serpentine windings of the river give it at least double that length. We have, therefore, a length of four hundred miles of the Missouri, and (for the same reason as applied to the Missouri) at least six hundred miles of the Platte, or one thousand miles of river averaging one mile broad, or one thousand square miles of rapidly moving river surface, exposed to a warm atmosphere, from which the evaporation is simply enormous. The Niobrara, counting its windings, adds five hundred more miles of evaporating surface. Unlike the floods of eastern rivers, these "big rises" last for a considerable length of time, often indeed from its beginning to its close, over two months. What adds greatly to the rapidity of the evaporations is the difierence of temperature between the waters of these rivers and the atmosphere. Lewis and Clarke, during their famous expedition up the Missouri in 1804, spoke of the sameness of the temperature of the water of the Missouri and its tributaries with that of the atmosphere. If no difference existed then, it does now. For example, the signal service at Omaha for June, 1878, report a

mean temperature of 68° 4'. My own determinations for the temperature of the water of the Missouri at the same point, being a mean of many observations for this month, give 63° 9', showing that the temperature of the water is for this month 4° 5' lower than that of the atmosphere. The mean temperature for July, 1877, at Omaha, as determined by the signal office was 76°. For this month the signal office also report the mean temperature of the river 73½°. The temperature of the water at the Platte at its mouth, approximates more closely to that of the atmosphere, it being for June, 1878, 68° and for June 1879, 67° 9'. At North Platte the temperature of the waters of the Platte is much lower, it being for June 65° and for July 68°. It should also be remembered that the temperature of the water is much more uniform than that of the atmosphere. Its daily oscillations are small. It is rarely during twenty-four hours the same as that of the atmosphere. From all these causes then the evaporation from the surface is very great and the winds carry the moisture in various directions, until finally it is again deposited as rain.

Nebraska Affected by the Amount of Precipitation of Moisture in the Mountains.

As the seasons of greatest rainfall in Nebraska are the seasons of greatest rise in the Missouri and the Platte, and as the magnitude of these rises is dependent on the amount of snowfall in the mountains, the moisture of the plains is to this extent dependent on the amount of precipitation there during the winter season. A question, therefore, in which every one here is interested, is whether the amount of moisture there is decreasing, is stationary, or is on the increase. Some scientific authorities have expressed the opinion that the whole Rocky Mountain region is in a comparatively rapid *process of drying up*, and that the amount of rain and snowfall must be less each decade and century. One of the theoretical arguments presentedin proof of this view is, that in ages geologically recent, the Rocky Mountain area was a region of great lakes, and that it then lay at a much lower level, but that now the lakes have nearly all disappeared, and that it is still rising at the rate of a few feet to the century, and that, therefore, in the nature of things, the drying-up process must continue. The facts relied on for this opinion, are mainly that wherever the mountain sides are from any cause denuded of their timber, no young trees

take their place. In other words, whenever the mountain sides become bare of forests, they remain so. It has also been asserted that many groves along the sides of the mountains and on the summits were dying off without any apparent cause, except the increasing dryness of the region. I am now confident that the advocates of this theory are mistaken in their theories and their facts. It is true that since the miocene tertiary age or even since the cretacious, the amount of water in the form of great lakes has on the whole been decreasing. But there are limits to these processes. There have been many revolutions in the condition, geological and meteorological, of central and western North America in the mesozoic and cenozoic ages. For example, during the earlier ages the greater part of western Nebraska was dry land. But it gradually and slowly commenced to sink, and in the course of centuries that are numberless, the Gulf of Mexico extended itself in a northwesterly direction over our plains to the Arctic sea. The uplifting of the Rocky Mountains that commenced at the close of the cretaceous age, inaugurated the area of making of dry land which has continued to the present time, but with many intermissions. My limits will not permit me to discuss these interruptions. But these facts in geological history do not warrant us to conclude, because in the most recent periods the tendency has been to continued elevation and dryness, that this tendency must continue. Rather should the opposite conclusion be reached, that sooner or later the limit of elevation and dryness will be attained, and that a reaction must follow as in the past. This reaction must for countless ages in the future bring increasing moisture. Now, the facts of the present operations of nature in the mountains do not sustain this theory.

The advocates of the increasing dryness of the mountains evidently make many of their observations at "long range." They have viewed mountain sides and tops like some newspaper men have battles—a great way off. Commencing at Georgetown I have climbed every mountain side and examined every mountain top that I could see where the timber had been destroyed from any cause. The whole number of such places that I examined was twenty-seven, and in every instance I found countless numbers of young pines and sometimes deciduous trees coming up to take the place of the old ones. Often when I looked at a mountain side from a distance nothing could be seen but old trees deadened by

fire. When, however, the spot was reached the ground was often so covered with young trees from one to five years old that it was difficult to penetrate through the mass of tangled limbs. Where small areas were not crowded with young trees the grasses were growing with a luxuriance that surprised many of the old residents of the mountains. Take for example the side of Griffith Mountain on the south side of Georgetown. The timber here was removed for fuel and other purposes. In spots over its denuded surface countless numbers of young pines, spruce and quaking asps from six inches to four feet high are making their appearance. Where squirrels and birds failed to plant seeds for another forest luxuriant grasses and magnificent flowers cover the ground. Every nook and corner among the rocks seems to be utilized for plant life. I found the same condition of things on the mountain sides around Middle Park. As all who have visited this beautiful region will remember, the mouutain slopes are here very densely timbered, and wherever I found the timber here destroyed by fires a young crop was struggling to take its place. On going north from Grand Lake for twenty-five miles along the western base of the main range, and in sight of the Rabbit-ear mountains, about twelve miles of my route, passed through fallen timber that had been destroyed a few years ago by a huge fire. Some sections of this desolation was already covered by a dense growth of pine from two to four feet high, while in other spots the young trees were just beginning to make their appearance. In some places it was hard to tell whether the grasses or the trees would gain the mastery. This section of the park is rarely visited, owing, probably, to the absence of roads or trails, and yet no part is more beautiful or has grander scenery. I was accompa nied by D. N. Smith, of Burlington, Iowa, and both of us were conducted by a notable guide, George W. Cole, whom we found exceedingly intelligent and perfectly reliable, and who never flinched when we were in a tight place. The rapidity of growth of the mountain timber has also been underestimated. I measured a great many pines and spruces in Berthoud Pass that had made a growth of from five to eleven inches during the year. Some quaking asps on Willow Mountain had made a growth of fourteen inches.

These facts, which, if space permitted, would be greatly multiplied, demonstrate that those are greatly mistaken who insist that

the Rocky Mountain region is drying up. The evidence, so far as it goes, points in the other direction, and proves that it is increasing. The agency of man probably has something to do with this, just as it has in Nebraska, but our limits will not permit a discussion of this point.

CHAPTER V.

WATERS OF NEBRASKA.

Lakes—Springs—Wells—Artesian Wells—Saline Springs—Rivers—Missouri—Platte—Republican—Niobrara—Keya Paha—White River—Elkhorn Logan—Bow Rivers—Nemahas—Blues, Loups, etc.

IN striking contrast to past geological times, there are now no large lakes in Nebraska. There are, however, a great number of small lakes in the State. From their small size and their distance from railroads they have thus far attracted little attention. Those along the Missouri, such as the ones in Dakota and Burt counties, have been produced in recent times, some of them indeed within a few years. The "cut-offs" of the Missouri often leave small lakes. The one northwest of Dakota City is about five miles long. Similar lakes, in a similar way, have been formed on the Elkhorn, the Platte and the Blue rivers. Many of these, however, in the interior, are the remnants of what was once, in loess times, a vast inland lake that covered the larger part of Nebraska.* An extensive region of small lakes is found at the head of the Elkhorn River. Of the lakelets that exist here, over thirty in number, many of them are of great beauty with sandy or pebbly bottoms. A still more extensive lake region exists at the headwaters of the North Loup, and between that and the Niobrara River. Most of these are of fresh water, but a few are saline or alkaline. At the head of Snake River, a tributary of the Niobrara, there are a number of small saline and fresh water lakes. Perhaps the most extensive groups of saline lakes are those at the head of Pine Creek, also one of the tributaries of the Niobrara. There are also a number of alkaline and fresh water lakes between the heads of the Dismal and Middle Loup. In my notes of exploration and travel there is

*See chapter on Superficial Deposits of Nebraska.

a list of over one hundred, and no doubt there are many more that have not been noted. In addition to these there are great numbers of ponds that almost approach in size to the dignity of lakes. Some of these lakelets at the head of the Elkhorn were in former years, when first visited, remarkable for the number of fishes that they contained. Unaccustomed to the presence of man, they seemed to have no fears of him. At least, when I waded into them they gathered around me in huge shoals. The alkaline lakes can always be detected on sight. No grass or other vegetable forms grow near the water, while at fresh water lakes luxuriant growths of vegetation extended to the very water's edge. With the increase of rainfall going on over the State, the level of these lakes will naturally rise, and many of them that are now isolated will become connected and cover much more extended areas than at present. A prominent characteristic of most of these lakes and lakelets is the wonderful clearness of the water. A silver three or five cent piece thrown into them can be distinctly seen at the bottom with the naked eye, even when they are from fifteen to twenty feet deep. This I ascertained in many instances by actual measurement. Most of the deeper lakes, especially of the northern and western portions of the State, have gravelly, coarse, sandy or pebbly bottoms. Here formerly, much more than at present, was a paradise of water fowl.

Springs, Wells, and Artesian Wells.

In the eastern half the State springs are abundant, and wherever the lay of the land and the underlying rocks are favorable to their existence. It is well known that however abundant rainfall and moisture may be, no springs are produced unless the waters that percolates through the soil are arrested by some impervious layers along which they can be carried to some break or cut, where they can flow out. Such impervious layers in Nebraska, are of two general types. The first type, are those on or among the underlying rocks, along which the water flows until it emerges on hill sides or edge of valleys. In south-eastern Nebraska, many springs appear on top of limestone strata that underlie loosely, compacted sandy rocks or shales. Where the Dakota Group of sand rock exists, springs frequently proceed above some harder layers of this deposit. Warner's Spring, southwest from Dakota City, in the bluffs, is an instance of this character. Another is a famous spring near Teka-

mah, in the bluffs, called sometimes, from the color of the rocks, Yellow Springs. The former has the rock above the spring covered with Indian hierogliphics. Occasionally springs proceed from or near the line of junction between these rocks and the next below. Some impervious layers of clayey, brownish shale in the Fort Benton Group, also arrest the downward course of water and leads it to the next break or valley of erosion to appear as a spring.

The se ond class of springs are those that proceed from between different kinds of layers of the drift and loess. The drift is specially remarkable for the number of clayey layers that are interposed between layers of sand and pebbles. These layers of clay carry the water to the nearest cut, where they form springs. Where these layers of clay do not exist, the water is carried along the top of the underlying rocks, if these happen to be hard or compact, and springs as in the former case appear on the edges of the valley. Many of the springs that emerge from the bluffs of all the river valleys owe their origin to these causes. This explains, too, why in many sections of the State, springs are found (often several of them on every quarter section of land), and why in other portions of the State they are found only at long intervals. The more broken or rolling, other things being equal, the more abundant they are. On the long reaches of nearly level land springs occur at much longer intervals. On and near the top of the level water sheds springs occur still more rarely.

Water, however, is abundant even here. Wells or borings always obtain it. Over the greater portion of the State, shafts or holes sunk down from fifteen to fifty feet are sure to obtain it in abundance. The exceptions to this rule are some portions of wide divides in such counties as Fillmore, Clay, Adams and Phelps, where there is a great thickness of loess and drift to be penetrated before impervious strata, capable of holding water are reached. Many farmers prefer land with no springs or running water on it. There is less waste, they claim. A well with a wind mill attached supplies water to man and beast in whatever quantity needed. A wind mill and reservoir attached to a well not unfrequently is made to water a thousand head of cattle daily, besides supplying the wants of a household.

Artesian Wells have been bored in a few places. The one in the public square in Lincoln is one thousand and fifty feet deep. It was put down in the hope that fresh water would be found. This effort

was a failure. At five hundred and sixty feet saline water spouted up a in powerful current. The contractor, Mr. Eaton, however, was uncertain whether the brine was here first struck, or whether a current of fresh water only forced it to the surface. It was certain that strong brine was found at the horizon between seventy and two hundred and fifty-five feet in the reddish sandstones of the Dakota Group. It did not, however, flow to the surface. The weight of evidence favored the conclusion that the salt water above was forced to the surface by the stronger currents below, especially as the tubing was so defective that all the waters encountered were intermingled. Between the level of five hundred and sixty feet and the end of the boring other artesian currents were struck, and the mingling of all that were encountered has given a well of water which, for variety of salts held in solution, is unsurpassed anywhere. An artesian boring was also made in Beatrice to the depth of twelve hundred feet, without, however, obtaining a flow of water to the surface. One has also been put down in Omaha, and a good flow of pure water obtained at a depth of 750 feet. On the whole, the geological formations of Nebraska are favorable for such wells. The general slope is upwards to the west and slightly towards the north. And although the tertiary strata overlie the cretaceous as we proceed westward, yet their thickness is far less than the rise of the country. The pressure of water, therefore, from between underlying rocks is sufficient to force it to the surface from some point between five hundred and twenty-five hundred feet.

Saline Springs.

There are several localities where saline springs or bogs exist. One of these is in Lancaster County, near Lincoln. The largest here covers approximately five hundred acres. Others of smaller area are not far distant. In this largest basin the water emerges in hundreds of places, and exhibits the curious phenomenon of varying in depth through the day. It is highest during the morning. It decreases through the day, and is at its lowest point about three o'clock in the afternoon. About this time any one passing over the basin and closely observing it will see the salt water bubbling up at hundreds of places. Where it comes up in this way the water contains about ten per cent. of common salt; at least that is the mean of several analyses, and is also indicated by the salometer. Many diverse opinions have been expressed about the value of

these salt basins. Some have regarded them as of little value and incapable of supplying brine in quantity sufficient to make it possible to compete with the great salt-producing sections of Michigan and New York; others again have placed an extravagant value on them, representing them as capable of building up princely fortunes for any who are fortunate enough to possess the capital to work them. The truth is probably somewhere between these extremes. If the salt water that flows away and is lost were placed in reservoirs and evaporated by solar heat, a richly remunerative business could be built up. Sooner or later this will be done. When the artesian well on the Government Square in Lincoln reached a depth of 560 feet, there was a heavy flow of salt water to the surface. The salt water, however, had been struck long before, but it did not flow out. The salt-giving rock is the reddish, porous sandstone that lies between seventy and two hundred and fifty-five feet in depth. It is because this artesian well was sunk down over a thousand feet and came in contact with many other strata of rock containing different kinds of water, that the flow now embraces so many different chemical elements Another artesian well had previously been bored on the north side of the main salt basin. This one struck a flow of salt water at about the same depth as the one on the Government Square. There is some uncertainty in the mind of Mr. Eaton, who made the borings in Lincoln, whether the "great flow" was produced by salt water, or whether the fresh water that was then struck simply combined with and forced out the salt water. All the known facts, however, go to support the view that salt water is here abundant, and only needs to be properly handled to make it a most profitable industry. There are also saline springs and lakelets beyond and near the head of the Elkhorn and Loup rivers, and at long intervals toward the northwestern corner of the State on tributaries of the Niobrara flowing from the south. I visited these under such unfavorable circumstances for investigation, that I am not prepared to report on their extent or probable value.

The Rivers of Nebraska

are distinguished for their breadth, their number, and some of them for their rapiditity and depth. In fact, the name of Nebraska means land of broad rivers.

Chief of all, not only of Nebraska, but of the United States, is the Missouri, because it gives character to all the rivers that unite with

it below down to the gulf. Forming the eastern border of the State, and a small extent of its northern boundary, and being tortuous in its path, at least five hundred miles of the river are on its western and southern side in Nebraska. It is deep and rapid. Its bed is moving sand, mud and alluvium. It no where in Nebraska has rock bottom. Before rock can be reached a thickness of from forty to one hundred feet of sand and mud must be penetrated from low water mark. Its immediate banks, sometimes on both, and almost always on one side, are steep—often, indeed, perpendicular or leaning over towards the water. It is generally retreating or advancing from, or on to one or other shore. It is the shore from which it is retreating that is sometimes gently sloping, while the one towards which it is advancing is steep. This steepness is produced by the undermining of the banks and the caving in that follows. Near the bottom there is a stratum of sand which being struck by the current is washed out and the bank falls in. Many acres in some places have been carried away in a single season. The principal part of this "cutting" is done while the river is falling. One of the places, famous in early Nebraska history that the Missouri in this way destroyed, is the town of Omadi, in Dakota County. Almost the entire town site is now in the river. When the river is low and winding through bottoms fringed with, in many places, dark groves of cottonwood and other timber, it is a sad, melancholly, weird stream. When it is "on a big rise," however, and presses forward with tremendous volume and force towards the gulf it becomes surpassingly grand and majestic. It is now full of eddies, and whole trees that have been undermined and have fallen into the river are dragged forward at a fearful velocity. It is never fordable. Boats of various kinds were exclusively used for crossing the river until the advent of the railroad bridge at Omaha. Another is now building by the B. and M. R. R. at Plattsmouth. The water always muddy or full of finely comminuted sand, the currant rapid and full of whirling eddies. It is a dangerous stream to trifle with. Often, indeed, during flood times does the boiling, seething mass of water look as if it had been stirred up at bottom with the sand by some mighty convulsive movement of the earth. Few that fall into it ever reach the shore alive without assistance. The clothes are soon saturated with the sediment of the river which is always turbid or muddy, and sinks the victim to the bottom. So well understood, however, is this feature of the Missonri that no more

persons are drowned in it than in other rivers of corresponding magnitude. The peculiar character of the Missouri gives uniqueness to the scenery along its shores. A position on some of the terraces or bluffs overlooking the river give views of unsurpassed beauty. There is one such of remarkable grandeur above Iona, in Dixon County, where the river touches the bluff, throwing its wide bottom into Dakota Territory. From this point the river can be seen towards the east for fifteen miles. The dark cotton wood groves, the curves of the river, the Dakota plain on the northern side, studded with homesteads, constitutes a picture that rivals in beauty the most famous scenes in the world. Another equally fine view of the river can be had from the top of the bluff on the road from Ponca to the Missouri bottom.

With some obnoxious elements attached to its character, it is as we have already seen, a storehouse of blessings to the sections through which it flows. Had it not been for the Missouri the settlement of this region would have been indefinitely delayed. It is a highway to the commerce and markets of the world; and on this highway the first emigrants reached Nebraska, and sent off their products to other regions. As the Missouri is navigable for two thousand miles above Omaha it was a great highway for traffic with the mountain regions of Idaho, Dakota and Montana. Since the building of railroads its business has fallen off. Vessels still run from Sioux City and Yankton to the upper Missouri and the Yellowstone. Latterly there are indications of a revival of business on the lower Missouri. Joseph A. Conner, Esq. has this season (Summer of 1879) shipped three boat loads of produce to St. Louis from Plattsmouth. The last load took down sixty car loads of corn and twelve hundred hogs. It cost him fifteen cents per hundred against twenty-seven cents which the railroads charged. Unfortunately, this competition only lasts through the summer. The Missouri is not navigable for five or six months through the winter season.

Next in importance to the Missouri is the *Platte* river. For length it approximates closely to twelve hundred miles. Its head waters originate in the mountains, and many of them rise in beautiful lakelets fed by the everlasting snows. No lakelets for example can be more interesting than those between the spurs of mountains twelve thousend feet above the sea level, where the Cache Le Poudre river is born. Though precipitous and eratic in Colorado

and Wyoming, by the time it reaches Nebraska it is broad, shallow, sandy, but still with a rapid current. It flows through the whole length of the State from east to west, dividing the State, but leaving the largest part on the north. In places at low water it can be forded, though teams are sometimes in danger of sticking fast in the quick sands. It is not navigable. It has been bridged at Fremont, Schuyler, Grand Island, Kearney Junction, North Platte and other points. An important point on the river is North Platte, where it forks, one branch being known as the South Fork, enters the State from Colorado near the angle of the southwest corner, or near the parallel of 41°. The North Fork enters the State from Wyoming near latitude 42. The average volume of water at North Platte is greater than at its mouth, though it receives in the meantime some large tributaries, the most important of which are the Elkhorn, Papillion, Shell Creek, Loup and Wood River. A few held that this was caused by evaporation. The tributaries, however, that enter the Platte from the north more than supply the waste from this cause. The explanation of this phenomenon is found in the character of the bottom and its continuation with the Drift underlying the uplands south of the Platte. The bottom of the Platte is extremely sandy, and is continuous with a sandy, gravelly and pebbly deposit of the Drift under the Loess as far as to the Republican. It will also be seen in the lists of elevations that have been given that the general level of the Republican is three hundred and fifty-two feet below that of the Platte. There is therefore a descent from the Platte to the Republican, and along such a formation that there is easy drainage from the one into the other. That there is such drainage on an extensive scale I have no doubt. Wading in the Republican in August, as I have done for many miles at a time, I noticed on the north side water ozing out of the drift continuously every few feet in places, and rarely at greater intervals than every few rods. Nothing of the kind was noticed on its southern shore. Where tributaries of the Republican from the northwest cut deep enough to strike the drift they share in the reception of this water from the Platte. Few, however, do this.

Flood time for the Platte is generally about the same time as that of the Missouri—sometimes a few days or weeks earlier, but the continuance of both is so long that they meet, though they rarely culminate together.

The Platte drains principally from the northwest. Its water shed on the south is generally only a few miles from its valley, while on the north it extends in places to within thirty-six miles of the north line of the State.

If the bottoms and channel of the Platte were favorable for it there would be an abundance of water for navigation. It is next to impossible for railroads going to the mountains to do all the business that will be demanned of them when the Platte Valley and the mountain regions are once developed. Cheaper freights than these that railroads furnish will also be demanded. Then a canal can be built along side of the Platte to receive its waters from the mountains to the Missouri. It could be made as the Suez canal was, largely from artificial stone. For such a canal the valley of the Platte is one of the best in the world. No one now living may see such a work, but Nebraska is capable of sustaining a population so dense that such a canal will be a necessity.

The Republican River rises in the Colorado Plains, near range 49 west of the 6th principal meridian. Here anciently there was a lake whose basin was about four miles across. The outlet, or river draining it, however, long since cut down the narrow rim and drained the lake. Its head here in the old lake is 4,050 feet above the sea. A few small springs now rise below the site of this old lake, and produce a tiny streamlet a foot across. Other streams, about or nearly as large, soon join it, but at the State line I could still,—when there in the spring of 1877, with D. N. Smith,—jump across it. Along this part of its course there are a few beautiful little lakelets into which and from which it flows. Here the water is cool, and clear as crystal. When it receives the waters of the Arickaree, about seven miles east of the State line, it assumes its characteristic character. It now becomes shallow and sandy, and in places rapid. Its principal tributary in this portion of the State is the Republican Fork, and comes from the southwest. Its junction with the Republican is in range 38, west. Frenchman's Fork is an important tributary that rises in Colorado, and, flowing southeast, joins the Republican at Culbertson. After this the most important tributary from the southwest is the Beaver. Red Willow and Medecine Creeks, from the northwest, are also important tributaries. An immense number of small creeks flow, every few miles, into the Republican, especially from the north. This river, unlike the Platte, increases regularly in

breadth and volume all the way from its source to its exit from the State, in Nuckalls County. It is forded in many places, and the only danger is from quicksands. There is little danger with a team that does not balk in the water. It is already bridged in various places. As was stated in the discussion of the Platte River, the Republican receives by subterranean drainage a portion of the waters of the former.

The Niobrara River, from its source, in Wyoming, to its mouth, is 460 miles long. Its source, in Wyoming, is 5,100 feet above the sea level. At the State line it is about ten feet wide, and of beautiful, clear, running water. Its elevation here above the sea level approximates closely to 4,594 feet. It continues to be clear and sparkling, but widening to about fifteen feet down to longitude 103° 15′. From this point it widens rapidly until, in longitude 102° 30′, it is from sixty to eighty yards wide. Here it enters a canyon whose walls are high and steep. This canyon region continues down to longitude 99° 20′, or about 180 miles. After its emergence from the canyon it is still a broad, rapid, sandy river to its mouth. Owing to its rapidity and quicksands, it is exceedingly difficult to ford in the lower part of its course. At least, this was my own experience. After sticking fast in the quicksands a few times, and being compelled to take a wagon apart and carry everything to shore, the river loses all romance for the explorer. In the lower part of its course there are many low islands, mostly covered with timber. It flows into the Missouri in range 6, west, and 32, north.

There are numerous tributaries of the Niobrara, most of which are of small size. On the south side, the first of importance is the Verdigris. This beautiful stream, which rises in Antelope County and flows north through the west end of Knox County, flows into the Niobrara six miles from its mouth. Between this and the mouth of the Keya Paha, on the south side, there are a great number of small tributaries. From the mouth of the Keya Paha to the Wazihonska there are also a great number of small tributaries, and the most of these are remarkable for the great number of fine springs of water which feed them, and for the groves of pine and oak on their narrow bottoms and on their bluffs. The word Wazihonska signifies, in the Dakota language, "the place where the pine extends far out." This stream is about forty-five miles long, and its valley, though much narrower, closely resembles that

of the Niobrara. Snake River is the next tributary of importance. Its mouth is near longitude 100° 45′. Its bed is thirty-five yards wide, and it has a narrow valley. Its bluffs are covered with pine. Beyond Snake River there are no large branches coming in from the south.

The Keya Paha is the first large tributary above its mouth on the north side of the Niobrara. It is about 125 miles long. Where I crossed it, fifty miles above its mouth, is has a fine valley, three-fourths of a mile wide, with a good soil, and some cottonwood timber. The bed of the river, like that of the Niobrara, is sandy, but its waters are clear, and delicious to the taste. At its mouth it is about fifty-five yards wide. The next tributary from the north-west is Rapid Creek, which, however, is only nine yards wide at its mouth. It connects with the Niobrara in longitude 100° 23′. Its valley is in some places half a mile wide, and the soil is, judging from the vegetation, quite fertile. A few small trees fringe its banks. It is about fifty-five miles long. Reunion Creek, which flows into the Niobrara at longitude 101° 18′, has hardly any bottom, and flows between lofty rock bluffs, very hard to ascend or descend. At its mouth it is fifty-eight yards wide, and has clear, cold, rapid-running water.

At longitude 101° 30′ a creek flows into the Niobrara, a little more than half the size of Rapid Creek, which it closely resembles. Above this there are a great number of small rivulets, which flow into the Niobrara, many of which are dry except in rainy weather- They, however, indicate the former abundance of water here, and will, with the growing moisture and rainfall of the State, again, no doubt, become permanent fresh-water streams. The peculiarities of *the exceptional characters of the Niobrara region* are given in a former paragraph under this head.

The White River flows through Northwestern Nebraska It enters the State from Wyoming, flows eastward and northeastward, north of the Niobrara, until it enters Dakota Territory, a little east of longitude 103°. It has its source not far from that of the Niobrara, near a sudden descent of 500 feet, south of Hat Creek Station, on the road from Fort Laramie. This abrupt descent, when approached from the south, is not suspected until it is reached. Sometimes this descent is a slope that a team can climb, and again it changes to a bare wall five hundred feet high. Numerous brooks flow down the gullies and ravines formed on the

side of this steep ascent and wall, and these go to form White River. The road from Hat Creek Station to Camp Robinson, thirty miles distant, lies near its base. "From Hat Creek the trend is a little south of east for thirty-eight miles to the point where this road makes its steep and difficult ascent." "Beyond this point it runs northeasterly for a few miles, then southerly until it meets and terminates the northern bluffs of White River, in the prominent landmark called Soldiers' Grove Cliffs, north of and overlooking Camp Roblnson." * * * "It was traced eastward to Camp Sheridan, forming the southern border of White River valley."—(*Captain Stanton.*) Hence, the river and its valley are shut out from the rest of Nebraska by this natural barricade on the south. On most maps of the State, this range is represented too far to the north. It forms in the midst of a valley otherwise easily traversed. The White River in Nebraska has many small tributaries, many of which are beautiful, clear rivulets. Except the ridge just mentioned, it flows through a rather gently rolling country.

The Elkhorn River, is one of the most beautiful streams of the State. It rises west of Holt and Elkhorn Counties. Near its source the valley widens to a very great breadth, and the bluffs bordering it are low and often almost inappreciable. In the region of its source especially south of the centre of the valley, are a great number of beautiful, small, fresh water lakes. Within a region eighteen by twelve miles square, there are at least twenty of these lakelets, most of which drain into the headwaters of the West Fork of the Elkhorn. It soon becomes in size a respectable stream. In the eastern border of Madison County it receives the North Branch of the Elkhorn, which rises in the southern part of Knox County. Unlike the West Fork, or main branch, it does not originate in a lake region, but in a region of innumerable small springs. The channel is full of water holes, between which the water often in midsummer flows under-ground. Soon it looses this character and becomes a rapid, clear, deep and beautiful stream. The general direction of the main river approximates to 250 miles. Its direction is southeast. It empties into the Platte in the western part of Sarpy County. For a large part of its course, the Elkhorn flows over rock bottom. It has considerable fall, and its steady, large volume of waters will render it a most valuable manufacturing region.

The Logan is the most important tributary of the Elkhorn. It rises principally in Cedar County. Of several branches of this river, it is impossible to tell which is the longest or deserves the name of principal stream. They all originate in bogs or old filled up lake beds. Large beds of peat are here found. After emerging from these bogs, which lie in the midst of the most beautiful and gently rolling lands conceivable, these Logan streams soon become constant, clear, and rapid. The bottoms are pebbly or sandy. There are many of these branches in Wayne County, which through their instrumentality, has among the finest physical features of any sections of the State. There are numerous smaller tributaries of the Elkhorn, all of which have characters in a miner degree like the parent stream. The general direction of all these Logan rivers, is southeast, until Burt County is reached, after which it is south, until a junction is formed with the Elkhorn in the eastern portion of Dodge County.

The Bow Rivers in northeastern Nebraska are not known as they deserve to be. They are known as the East, the Middle and the West Bows. No rivers of the State have interested me more. The water is clear and cold. They originate in the coolest and most delightful springs of mostly soft water. In the centre of Cedar County, near Curlew, there is a spring of cold water that emerges from a bluff strong enough to turn a mill. In fact, almost every half mile, along these rivers, these magnificent springs make their appearance. Except the East Bow, their general direction is northeast. The East Bow flows northwest until it unites with the Middle Bow. Below St. James, all united they join their waters to those of the Missouri. Sooner or later, when fish culture receives the attention in this State, which it deserves, these Bow Rivers will become noted as trout streams.

The Nemahas early became noted rivers in Nebraska. The north branch of the Nemaha runs in a southeasterly direction, diagonally through Johnson and Richardson Counties, until it unites with the main river, in the latter county. Its length is about sixty miles and increases regularly in size, from its source to its mouth, by the addition of numerous tributaries. The main Nemaha rises in Pawnee County, takes a southerly direction into Kansas, then turns northeast into Richardson County and then flows a little south of east, until it unites with the Missouri near the southeast corner of the State. Its length is but sixty miles,

but it receives so many comparatively large tributaries, that its magnitude at the end of its course is much greater than many much longer rivers. The bottom lands of these rivers are broad, often beautifully terraced, and the bordering bluffs are gently rounded off. The impression left on the mind, after traversing these valleys, is that their beauty cannot be surpassed. The fall and size of these rivers and their larger tributaries, will supply motive power to an immense number of manufacturing industries. The Little Nemaha is a smaller edition of the "Big Nemaha." It rises in Cass County, flows in a southeasterly direction through Otoe, and Nemaha Counties, and unites with the Missouri near Nemaha City, in Nemaha County. It also has numerous tributaries. It is a beautiful stream of water, and with its characteristic wide bottoms and gently rounded bluffs, gives character to the counties through which it flows.

The Blues are among the most important rivers of Nebraska. The main branch with its tributaries drains eight counties, which are among the best in the State. It is about 132 miles long. It rises in Hamilton County, and after flowing for thirty-six miles, a little northeast, it curves around and follows a southeast direction through Butler, Seward, Saline, and Gage Counties. It enters Kansas from the Otoe Reservation, where it ultimately unites with the Republican. The Middle Fork of the Blue also rises in Hamilton County, and flowing first a little north of east, unites with the North Blue at Seward. Its length is about sixty miles. The West Fork of the Big Blue rises in Hall County and flows a little north of east through Hamilton, then east through York, and then southeast through Seward, and finally unites with the main Blue, five miles above Crete in Saline County. School Creek and Beaver Creek are tributaries of the West Fork of nearly the size of the parent stream. Turkey Creek is also a large tributary from the northwest, which unites with the Blue near the line of junction, between Saline and Page Counties. All these Blue Rivers and their tributaries, few of which can even be alluded to, are remarkable for the amount of water which they carry off, and the great beauty of the bottom lands through which they meander. The uplands between the bottoms are also for the most part gently rolling and composed of the richest soil. The bottoms are often terraced, and the materials in such cases are mostly of a Loess character. The bluffs bordering these bottom

lands are generally gently rounded off, and infinitely varied. It is doubtful whether the mind could imagine a section better supplied with rivers and creeks and rivulets giving an abundance of water privileges of the best character. There is such an abundance of water in these rivers and their tributaries, and the fall adequate, that the motive power is ready to propel a vast amount of machinery for manufacturing industries. With superior water privileges and the choicest lands a dense population must here rapidly accumulate.

There is still another Blue River that rises in Adams County and flows in a southwesterly direction through Clay, Nuckolls, Thayer, and in the southeast corner of Jefferson County, enters Kansas where it finally unites with the "Big Blue." About 110 miles of this river are in Nebraska. In its most important features, it resembles the "Big Blue." Like the last, it is a magnificent stream. It also has numerous tributaries, which are in miniature, what the parent stream is.

The Loups, next to the Niobrara, are the most unique rivers in Nebraska. Even these streams, however, have many things in common with the other rivers of Nebraska. The whole length of the middle or main Loup approximates to 250 miles. It rises a little east of the 102° parallel and fifty miles from the north line of the State. My barometer indicated 3,230 feet above the sea level for this point. There are a great number of small lakes and lakelets. I counted nine within a radius of ten miles. Some of them drain into the Loup. It flows in a southeastern direction until the southeast corner of Howard County is reached, when it turns first a little north of east, and then a little south of east, and unites with the Platte, near Columbus, commencing at its lower end on the north side. Its first important tributary is the Beaver, and then Cedar Creek, which originally took its name from the Cedar Groves along its banks. The North Loup also rises among a cluster of small lakes, a little east of the 101° meridian and forty-five miles from the north line of the State. Here I found a dozen of small lakes within a radius of eight miles, and many of them of great beauty, with pebbly and sandy bottoms, and with water clear as crystal. Calamus Creek is its most important tributary. I regret that I failed to reach its source. The entire length of this Loup, until its junction with the Middle Loup is 150 miles. Its general direction is southeast. Perhaps there is no more interest-

ing and beautiful valley in all Nebraska than the North Loup. The water is of crystal clearness and the fertility of the valley is very great. The scenery is varied. This judgment formed twelve years ago, is more than confirmed since its settlement. Corn and the cereal grains are most successfully produced. Timber and fruit trees are grown with an ease surpassed nowhere in the State.

On the south side the main tributaries are Mud Creek and the South Loup. This latter river rises immediately beyond the west boundary of Custer County, and flows in a southeasterly direction into Buffalo County, and then northeast to its junction with the Middle Loup in Howard County. There are a large number of smaller tributaries. The rivers are in places excessively sandy and quite rapid. The quality of the bottom lands vary more than in other Nebraska valleys. There are many sandy elevations here. At the ordinary level there is a somewhat sandy loam, rich in humus and of a dark color. In depressions slightly below the level of the former, and often of a cloggy texture, the alkaline soil occurs. Slightly elevated above both these varieties is a coarser sandy soil. These different soils often shade into each other, and again they are sharply outlined. The good soil, however, greatly predominates over the inferior varieties. Very little of the alkaline soil however can be called poor. Cultivation permits the waters to percolate through it and carry to lower levels the excess of alkaline matter, and much is consumed by the crops that are cultivated, especially in wet seasons. Here as elsewhere over the State, where these soils occur, a few years of cultivation often renders them equal to the best in the State.

Towards the head of the Loups the sand hills in places crowd the bottom lands. Where they occur travel is difficult. Often where they are most abundant they suddenly cease and the country changes to a gently rolling plain of first and second class land. Some explorers have pronounced one-half of the region of the Loups waste land. This is certainly by one-half too high. And if one-fourth of the upper Loup region is taken up with sand hills they still make choice pasture or grazing grounds. It is remarkable that where twelve years ago the sand hills were comparatively bare they have now, through the influence of increasing rainfall, become covered to some extent with a growth of nutritious grasses. This is proof, if any were needed, of the abundance of mineral fertilizers which these sands contain.

Salt Creek derives its name from the number of saline springs and bogs that unite with it in Lancaster County. It is formed near Lincoln by the junction of Oak Creek, Middle Creek, South Creek and other small streams. From this place it flows in a northeasterly direction until it unites with the Platte below Ashland. It is a rather deep stream with a muddy bottom. Its valley is composed of remarkably fine bottom lands. The slope from the bottom up to the top of the bluff on the southeast side is exceptionally gentle. In many places it is impossible to tell where the bottom leaves off and the upland begins. The characteristics of the salt springs are discussed under the head of the Historical, Superficial and Economical Geology of the State.

There are many other rivers of Nebraska to which our limits will not permit us even to allude. Important, however, among these are the Weeping Water in Cass County, the Wahoo in Saunders County, Elk Creek in Dakota County, and South and West Iowa Creeks in Dixon County. All possess more or less of the general character of Nebraska rivers. Traveling over the State in almost any direction, and the study of a good map, demonstrates that this State is eminently the land of many and broad rivers. Many of the smaller streams, however, in eastern Nebraska are losing their character of broad and shallow streams. They are becoming deep streams. They have, since the settlement of the country, been cutting deep between their banks. Many streams which sixteen years ago could be stepped across are now wider, and very much deeper than then, and running between such high banks that they can only be readily crossed by bridges. Shut out from the influence of the sun their evaporation is much less, and their size increases from this cause as well as from the increase of rainfall.

The water supply, therefore, of Nebraska, is most bountiful. Rivers or creeks—often both—are found in every county. The number of rivulets is enormous. Where springs fail to appear water can be obtained by wells.

The Water Power

of Nebraska is simply enormous. As the rise of the State towards the west approximates to seven and a half feet to the mile, the fall of most of the streams averages at least one-half of that. Were the streams straight, they would average the same fall as the rise of the country,

but they all meander more or less through their wide bottoms. Every few miles, however, places can be found on most of the creeks and rivers where the fall is from seven to ten feet to the mile, and even more, for the reason that the descent is very irregular, being much greater at some points than at others. Where there is no fall for a mile, it is made up by a more rapid descent further on. Counting in then all the creeks and rivers of the State the motive power that is now wasted and waits to be used is beyond calculation.

The dams built across the Nebraska rivers are best modeled after those of the beavers. These brute engineers constructed their dams by laying sticks and twigs up and down the streams across their currents, and filling in the interstices with mud. It has been found by experience that mill dams constructed in this way, with brush, wherever there is no rock bottom, most successfully resist the action of floods. In fact, very few dams well built on this plan have ever been disturbed by the severest freshets.

CHAPTER VI.

DRAINAGE OF NEBRASKA AND CHARACTER OF ITS WATER.

General Character of the Drainage—Character of the Water—Source of Impurities—Character of the River Water—Temperature of the Missouri River Water—Water of the Platte, Republican and Bow Rivers.

General Character of the Drainage.

FROM the preceding presentation of facts, and the discussions concerning them, it is clear that the drainage system of Nebraska is complete. The State, as a whole, slopes eastward, and a little southward. There is little flat land. The great body of the State varies from a very gently, almost imperceptibly rolling region, to one that is made up of rounded, hill-like masses, with long, gentle slopes. The subsoil is the best in the world for drainage, being made up principally of Loess materials, and, where these run out, is composed of Alluvium, or Drift. The Loess contains eighty per cent. of finely comminuted silica, and as this deposit is of enormous average thickness, it absorbs excessive rainfall like a sponge. The Alluvium also contains a large amount of silica, and the Drift is noted for that material. The average elevation of the whole State is about 2,312 feet above the sea. In the lay of the land, therefore, its physical character, its slope, and elevation above the sea, it is in the best possible condition for perfect drainage. It is owing to this combination of causes that farmers are seldom, in the wettest weather, delayed more than a day or two in plowing. In fact, as soon as the rain ceases, in most soils, they can plow without injury to the land. It is also owing to these causes that Nebraska possesses such admirable natural roads. Twelve hours after the heaviest rains the roads are comparatively dry. It is true that roads that cross creek bottoms are sometimes an exception ; and this is because occasionally there are longer or shorter distances here that are underlaid with strata of clayey material. Here the

water stands longer, and in the rainy season the mud may continue for a few weeks or a month. Such cases only attract attention because of the general dryness of the roads. Less road tax is needed than in any other State. The obstacles to good roads are the creek and river crossings, which are everywhere being rapidly bridged. It is sometimes objected that there are peat bogs in the State, and, at long intervals, a few marshes. These are, however, the remnants of old lakes, and these, having a small accumulation of clay on their bottoms, retain the water, and make possible that accumulation of peaty matter, much of which may eventually become important for fuel.

Character of the Water.

The commonest ingredient of the water of springs and wells is carbonate of lime. Then follow, in minute and varying quantities, in different springs, carbonate of potash and soda, sulphate of potash, magnesia, soda and lime, chlorides of sodium, and potassium, and iron and free carbonic acid. Many springs are free from the most of these salts. Carbonate of lime, the commonest of these impurities, is seldom present in injurious quantites. Perhaps three-fourths of the springs and wells of the State contain it, in amount varying from a trace to distinctly hard water. There are many springs and wells whose waters are remarkably soft. Those along the Bow Rivers are mainly of this character. Generally, where springs emerge from the gravel beds and pebble, or strata of sand in the Drift, the waters are soft, and otherwise remarkably pure. Wells sunk into such deposits are also apt to be free from lime, or contain it in only minute quantity. On the other hand, water obtained in the Loess, whether from springs or from wells, has a perceptible quantity of carbonate of lime, and a small quantity of iron in solution. There are also strata in the Drift containing a large amount of lime, and this often is the source of the hardness of the water that proceeds from this deposit. In general, the water of springs and wells is remarkably clear and cool, and free from injurious ingredients. The reader, of course, understands that such a thing as absolutely pure water is an impossibility, except by distillation. It is the salts that natural water contains that make it palatable. It rarely happens that any organic matter is present in a spring or well, unless it gets there through the carelessness of men. This leads us to consider the

SOURCE OF IMPURITIES.

Sometimes the water of springs and wells has a disagreeable taste from an excessive quantity of iron that is present. It may be a peroxide of iron, but more frequently it is a sulphate or sulphuret. This is particularly the case with springs and wells that flow over or through rocks of Cretaceous age, abounding in iron pyrites, the decomposition of which, and combination with the water, gives it its peculiar iron and sulphur taste. The Dakota group, for example, abounds in peroxide of iron, and the Fort Benton group in iron pyrites. Some strata of the upper carboniferous equally abound in the compounds of iron. I have sometimes been called on to decide the character of such water, on the supposition that it was impregnated with organic matter, but, on analysis, nothing could be found except iron and sulphur, besides the ordinary salts that are universally present. Such waters are probably more disagreeable than unhealthy.

Impurities from the presence of organic matter in water are far more fatal to health. There is no need for the occurrence of such cases, but, unfortunately, through ignorance or carelessness, they do occur.

It sometimes happens that filth is permitted to accumulate near wells, and, too often, all unsuspected, drains into them from the surface. Owing, however, to the porous nature of the soil, filth more frequently drains into them by subterranean passages. I have frequently been called to examine well water that was believed to be the cause of illness in families. Often I found organic matter, which frequently was partly composed of uric acid. The source could universally be traced to a sewer, vault or cattle-yard near by. In fact, in such a soil as that of Nebraska, no filth, and especially no sewer matter, should ever be placed within seventy-five feet of a well or spring. It is almost absolutely certain to drain into a well if closer than that. One hundred feet, or more, would be a safer distance. This is often inconvenient, and sometimes nigh impossible in towns. Under such circumstances, where water works cannot be provided, families should depend on filtered cistern water for household use. Where rainfall is as abundant as here, cisterns can be made capacious enough to supply water for households during the whole year. More sickness, I am confident, is caused by well water that has been permitted to become tainted

by foul matter than from all other causes. Even in the country, where these faults could so readily be avoided, wells are too often located alongside of the cattle-yard, or close by a cesspool. The inevitable consequence is, that the water sooner or later becomes impure, by the presence of decayed animal matter.

Another source of impurity, though by no means as dangerous as the last, is the curbing used for wells. The water of wells often gains a bad repute by the disagreeable taste and odor given to it by the cottonwood or pine lumber which is used to protect them from caving at the bottom. The first settlers, before stone quarries were opened, or brick were burned, resorted to this method to secure their wells. It is still practiced to a large extent in many sections of the State. Frequently, in examining wells that were declared to be unfit for use, nothing was found the matter with them except this wooden curbing, which had imparted to it its own taste.

Character of River Water.

The waters of the creeks and rivers of Nebraska must necessarily vary a great deal in character. That of the Missouri is the most peculiar. It is always muddy. It has this character to the mouth of the Yellowstone, above which the Missouri is, for a larger part of the year, a clear stream. It is the Yellowstone that gives character to the Missouri, it being, like the Missouri below their junction, turbid to its source. In 1873 I collected water from its channel, at Omaha, during high water, when the bank was nearly full, and in October, during low water, at the same place. The sediment was separated by filtration, and the amount was as follows: At high water, 403.7 grains from one gallon; at low water, 51.9 grains from one gallon.

This result differed slightly from that of Prof. Emmons, of the Iowa geological survey. His determination was as follows: At high water, 404 grains per gallon; at low water, 52 grains per gallon. The amount of suspended sediment at high water is, therefore, upwards of seven times as much as at low water. It was found, however, that the amount of solid matter held in solution, was greatest at low water. This would naturally be expected, as during flood time the sediment has but recently been added to the water, but by the time low water arrives, the river has exercised its solvent powers. In the chapter on the Superficial Deposits of Nebraska, the reader will find analysis of Missouri River sedi-

ment. Only a qualitative analysis was made of the water with the following result:

Carbonate of lime was present in the largest quantity. Next came carbonate of soda, iron in various forms and carbonic hydrochloric acid. In smaller proportions there was present sulphuric acid, magnesia, and organic matter. Only a trace of potash appeared. Iron was clearly most abundant at high water.

The temperature of the Missouri River at Dakota City during

May, 1869, was........ 60°
June, 1869, was........ 62°
July, 1869, was........ 70°
August, 1869, was........ 73°
September, 1869, was........ 66°
October, 1869, was........ 54°
November, 1869, was........ 36½°
December, 1869, was........ 35°

The above were my own observations. The following are taken from the report of the United States Signal office at Omaha during 1877 and 1878.

	Temperature at bottom.		Average depth of water.
	Max.	Min.	Feet.
July	77	70	26
August	..	..	..
September	72	64	10
October	66	46	10
November	45	32	10
December	38	32	14
January	..	.	..
February	..	..	..
March	52	37	10
April	..	..	..
May	..	..	..
June	..	..	..

During several years between 1873 and 1879 I attempted to ascertain the temperature of the Missouri at Plattsmouth, but the result did not differ materially from the above.

Though the water of the Missouri is muddy, yet when it is allowed to settle and become clear, it is singularly sweet, and in summer, when cooled with ice, it is even delicious. I have seen barrels filled with Missouri water, in July and August, and whether standing in the sun or shade, no infusoria or other minute animal forms could be detected with the microscope, even after a week's exposure. I have had no such experience with any other river water anywhere. Probably, one reason of this is, that the sediment held in suspension, by the water, carries to the bottom, as it settles, all organic matter. Eventually infusoria appear in it—in

from ten to twelve days, while with ordinary water, under the same circumstances, they can be found within a week.

The waters of the Platte do not differ materially from those of the Missouri. It holds almost as much sediment in suspension during flood time, but materially less during low water. In 1874, I took a sample from the Platte, near Omaha Junction, in flood time in June, and one from the same place, at low water in October. The following result was obtained by filtering. At high water, 397 grains from one gallon; at low water, 39 grains from one gallon. It is seen from this result that the amount of sediment held in suspension by the Platte, during high water, is over ten times as great, as during low water. The difference is much greater than between high and low water, in the Missouri. In other words, the Platte much more nearly becomes clear than the Missouri. The qualitative analysis also showed the presence of lime, soda, iron, carbonic and hydrochloric acid. Then in less quantities followed sulphuric acid, magnesia, potash, and organic matter. There was less lime and iron, and more potash than in the water of the Missouri. Analyses varied considerably between high and low water, and between samples taken at different places. The above is, therefore, only an approximation to the correct composition of the water.

The temperature of the Platte waters is comparatively high. At or near its mouth, its average for June, 1879, was 69°; for July, 76°, and for August, 78°. When, however, the water of the Platte is left to settle, and become clear, it can safely be used for domestic purposes. It is purer than that which is used by the majority of mankind.

On analysis, it is found, that the water of the Republican closely resembles that of the Platte. As it receives by drainage a considerable quantity of the water of the Platte, and flows over similar deposits, this similarity in chemical character would be expected.

The Niobrara River varies in different parts of its course in the quality and temperature of its waters, more than any other river in Nebraska. Where it enters the State, it is a clear, sparkling stream, and before it reaches the canyon region, it approximates in character to that of the upper Platte. Here, however, it flows between lofty walls and receives such a vast number of cold springs of water, that the whole river partakes of their character. After it emerges from this canyon region, it again gradually approximates in the character of its water to that of the Platte.

The Bow Rivers, as we have already seen, are peculiar in the great number of pure springs of water, that are found along their whole length. Their mean temperature is, therefore, somewhat lower than that of other rivers of the State. And yet because of the springs with which they are directly fed, large sections of them never freeze, even in the coldest winters. For reasons previously stated the water of these rivers is less hard than that of other rivers of the State. The only other river with which I can compare it, in these respects, is the Bazile, and in a still less degree, the Verdigris. The Bazile, like the Bows, is largely fed by springs flowing directly into it.

The waters of the remaining rivers that rise within the State have many points in common. One of them is the blackish hue that is given to them after rains and during flood time. This is caused by the organic matter which is brought down by every rivulet from the black surface soil of the State. This black soil being from one to twenty feet in thickness, all the water pouring into the rivers, after rains, is more or less, loaded with it. This, then, gives to the waters those ingredients which constitute its dissolved substance. Among these in addition to the organic matter, is lime, salts of soda, potash and magnesia, and iron. In minute quality, also, sulphuric and hydrochloric acid. When flood time is over, the streams that rise within the State, are proximately clear. The Blues have in places, a blue tinge, and yet objects can be seen at the bottom, where the water is from two to four feet deep.

CHAPTER VII.

GENERAL FLORA OF NEBRASKA.

AN OBSERVER casually passing over the State little suspects the wealth of vegetable forms that clothe the land. To understand, however, its botany, this one fact needs to be borne in mind, namely that Nebraska is the meeting place of two somewhat diverse floras. Here the plants indigenous to dry regions and those common to humid sections come together. The slope of the land eastward is so gentle that Rocky Mountain forms come more than half way to meet their distant relatives from the moister regions of the Missouri and Mississippi. In fact here Rocky Mountain plants by slight and gradual change in environment, have adapted themselves to a climate very different from their native habitat. The same can be said of forms whose centre of dispersion was the Mississippi basin. Hence it is that the best botanical floras of the schools—such as Gray's Manual and Wood's Class Book—do not describe many of our floral forms. Singularly enough what they leave off can mostly be found in Porter's and Coulter's Colorado Flora. The former were only intended for the region east of the Mississippi, but this section, in addition to that, grows many of the plants of the Rocky Mountains. This is one reason why there is such a wealth of vegetable forms in the State. It has drawn for its supplies from two diverse regions, and owing to the magnificence of its climate, and the richness and variety of its soils, it has successfully acclimated plants from high, dry and cold regions, and those from low, humid and hot sections. I have thus far collected over 2,100 species and varieties of plants from this State.* Comparing this number with the lists from other States, it will be seen that our wealth of native varieties and species is exceptionally great. And yet the harvest to be gathered, especially among the lowly cryptogamic forms, is hardly touched.

* See my Catalogue of the Flora of Nebraska, published by the University of Nebraska, 1875. The next edition will have at least 100 additional species.

The highest of all the orders, the Crowfoot Family (*Ranunculaceæ*) is represented by forty-two. Characteristic among these for their humble beauty are six species and one variety of Anemone. Five species and one variety of Crowfoot (Ranunculus) are abundant in their season. The Larkspurs (Delphinium) are still more abundant. No species, however, of this family is so remarkable for its beauty and abundance as the Columbine (Aquilegia.) They are a conspicuous form along the line of the Burlington & Missouri Railroad in Nebraska, between Ashland and Plattsmouth. Here they grow to a size, and attain to a beauty rarely witnessed elsewhere.

Among the early flowering plants the violets here, as elsewhere, hold a conspicuous place. No temperate region is complete without them. Eleven species adorn our prairies and woodlands. One of them, the Downy Yellow Violet (*Viola pubescens*) is found only in the belts of timber. The Larkspur Violet (*V. delphinefolia*) and the Arrow-leaved Violet (*V. sagittata*) are the most abundant. Their abundance sometimes is so great in woodlands that they give a violet hue to the ground and exclude all other forms.

In the Pink family no flower is so abundant as the Starry Campion (*Silene stellata*). Its favorite locality is the thick underbrush of woodlands.

The Mallows are represented by some delicately beautiful forms. Chief among these is one with scarlet flowers and branching stems (*Callirrhoe involucrata*). Another (*C. triangulata*), is more abundant, and only less beautiful than the last. Another, with a scarlet salmon color, shading into yellow purple, grows in patches covering the ground. This is one of the most desirable for cultivation. Two species of Hebiscus are abundant, but one of them (*H. triornum*) which has become abundant in many parts of the State, is a foreigner, having escaped from cultivated grounds.

The Pulse Family (*Leguminosæ*) are exceedingly abundant in species and individuals. One of the earliest of the species of this order to bloom is the Ground Plum (*Astragalus caryocarpus*), so called by the early "*voyageurs*" over the plains. Its young tender pods are no mean substitute for peas, as I many times ascertained by experience when camped on the unsettled prairies. Its purplish violet racemes of flowers which often shade into white, are the most conspicuous forms on the plains in their season. There are nineteen other species of Astragalus in the State, many of which with intense scarlet flowers are marvelously beautiful.

They increase in the number of species towards the western part of the State, their centre of distribution being the Rocky Mountains. Other characteristic forms of this order are the Psoraleas, Prairie Clovers (*Petalastemon violaceus and P. candidus*), Tick-Trefoils (*Desmodiums*), and Indigo Plants (*Baptisia*). Baptisia leucophaea, with its large racemes of cream-colored flowers, is abundant, and arrests the attention of every one traveling over the prairies when it is in bloom. The Wild Senna (*Cassia Mari landica*) is exceedingly abundant and largely sensitive, and full of beautiful yellow flowers is one of the most interesting plants in the State. Still more highly sensitive is the Sensitive Brier (*Shrankia uncinata*). Its rose-purple flowers are in small heads, and is most abundant in Southwestern Nebraska.

Of the Rose Family there are fifty-nine species in the State. Of these the wild plums are the most conspicuous. These are found in almost every county, and grow to a size and spread into varieties, and attain a richness of flavor rarely equaled elsewhere. The Cinquefoils (*Potentilla*) are represented by fourteen species. The wild strawberries, raspberries and June berries are all well represented. Of wild roses there are at least four species. Occasionally one of these (*Rosa blanda*) becomes a nuisance, its eradication being difficult from old formerly abandoned fields.

The Evening Primrose Family (*Onagracea*) gives many beautiful forms to the State. One of these (*Œnothera biennis*) which has been successfully reduced to cultivation, is found growing in Western Nebraska with flowers three and four inches in diameter. Another one, growing in Central and Western Nebraska, is still larger, but with a low stem, and the flowers light yellow, with orange veins. One of the commonest forms of this order in Eastern Nebraska is *Œnothera serrulata.* Its flowers are yellow and its leaves narrow and serrulate. All the species of this order increase towards the western limits of the State.

One of the most curious of all orders is the *Cactus Family.* Of this order there are in this State twenty species and varieties. Along the eastern counties the commonest forms are *Opuntea vulgaris* and *O. Rafinesquii.* They increase greatly in numbers of species and individuals towards the central and western portions of the State. One of the most beautiful is the *Cereus caespitosus.* It is of a short cylindrical form, with rose purple flowers two and three inches in diameter. The yellow flower becoming green of

C. viridiflorus is scarcely less beautiful. Many admire most the large, deep purple flower of *C. fendleri*, and the scarlet one, open day and night, of *C. gonacanthus*. The varieties of colors among these flowers is exceptionally great, shading from pink purple to yellowish green, and from deep scarlet to rose purple and yellow.

The Honeysuckle Family is represented by fourteen species, the most common being the Yellow Honeysuckle (*Lonicera flava*). The Sweet Wild Honeysuckle (*L. grata*) is abundant in the State. The Hairy Honeysuckle is rarely met with. The Bush Honeysuckle (*Diervilla trifida*), so common in the East, is also abundant here on the borders of woodlands.

The Composite Family is the most abundant in the number of species of any in the State, there being at least 244 different forms. Some of the earliest and some of the latest flowering plants belong to this order. One of the former is *Townsendia grandiflora*. Almost stemless, crouched among the dead grass, it is a most beautiful object amid the bleakness of early spring. There are nineteen species of sunflowers. These in the latter part of summer and autumn everywhere attract attention, and still later by their seeds furnish food to great nnmbers of grouse, quail and other birds. The beautiful blazing stars (*Liatris*) are represented by six species. The asters here find a most congenial home, as twenty-eight species adorn our prairies. The Golden Rods (*Salidago*), so well loved by the bees, are represented by twenty species. The Coreopsis, so much sought after and cultivated in the east is represented by eight species. A short distance northeast of Fairmount, acres are covered with these golden-hued flowers, to the exclusion of all other forms. One of the most universally spread of this order is *Aplopoppus rubignosus*, and *A. spinulosus*. The former is peculiar in being "viscidly pubescent," the flowers in subglobose heads, and generally have many, on erect stems from ten to eighteen inches high. It is one of those curious forms that has spread over the State from the lofty regions on the west.

The finest representative of the Lobelia Family is becoming exceedingly rare. I refer to the cardinal flower (*L. cardinalis*), which was abundant along the Missouri wooded bluffs, but is now rarely met with.

The Figwort Family finds here a most congenial home. Twenty species of Pentstemon grace the State; only six, however, are found

in the eastern counties. They increase rapidly westward, until the mountains are reached, where they have their greatest development. Among the most beautiful are *P. grandiflora* and *P. ceruleus*. *P. albidus* is only found along our western border. More of these beautiful species deserve a place in the garden than have yet been admitted there. The scarlet Castilleias, in western Nebraska, are not less beautiful than the last. The rose-purple Gerardia also abounds in places. It is curious that a homely member of this tribe, the common mullein of the East, though not native, has, since its accidental introduction, spread rapidly over eastern Nebraska.

The Verbenas are among the most generally spread species of the State. Some of the native nine species of the State are found in every county. *Verbena hastata* is most abundant. *V. bracteasa* is at home in every county. I have seen it grow at the very edge of the Bad Lands, and at the foot of the Sand Hills.

Of the forty-eight species of the Mint Family, perhaps the most attractive is *Salvia azurea*, which grows here from four to five feet high, with showy, azure blue flowers, in a spike-like raceme.

The Polemonium Family receives here a wonderful development in the number of individuals. Phlox is the most abundant. In June, in many places, the prairies are made scarlet by their numbers. Some of the counties along the Elkhorn and its tributaries are particularly remarkable for their numbers. The Logan bottoms, in Wayne County, in former years, had a most extraordinary profusion of these flowers. The Gilias are most abundant towards our western limits. One form, however, (*G. tricolor*), first described from California, is frequently seen in eastern Nebraska.

Of the Convolvulus Family, the most interesting form is the Bush Morning Glory (*Ipomœa leptophylla*). Its purple, funnel-form flower, three inches long, is a most attractive object in southwestern Nebraska. The dodder, also, unfortunately, abounds in our woods.

The Night-Shade Family is represented, among many others, by the Potato-Beetle weed (*Solanum rostratum*). It was introduced from the mountains by freighters across the plains. It is the original plant on which the potato beetle fed, before the more luscious potato came in its way.

The Gentian Family is most fully represented by the type genus *Gentiana*. Of the fourteen species that here belong to this order,

6

nine belong to this genus. They are rarer than in former years, *G. crinita*, or fringed gentian, being now rarely found. One species, with a short stem, is a very late bloomer in autumn. It is of a very deep blue color, and appears after the first frosts.

The Milkweed Family is particularly rich in species of the genus Asclepias, of which there are fourteen different forms. *Asclepia verticillata*, with its greenish-white flowers, is rapidly, for some reason, increasing in southern Nebraska.

The Buckwheat Family is represented by forty-two species. The joint-weeds (*Polygonum*) are the most abundant. Of these there are nineteen species and varieties. *Polygonum amphibium* and its two varieties, are the most abundant, it being found abundantly in low, swampy ground. The Missouri bottoms seem to be its centre of distribution. The plant is remarkable for the large amount of tannic acid which it contains.

The Spurge Family is conspicuous in the State, not for the number of species, as there are only twenty-two, but because of the singular appearance of a few forms. *Euphorbia marginata*, so abundant in every county, is conspicuous for its beautiful silver-white margined leaves. These are recognized a great way off. This plant is cultivated in the east for its beauty of form. Here, in places, its very abundance makes it a nuisance. *E. heterophylla*, on the other hand, has a beautiful scarlet-red base to its upper leaves. This species does not make itself so conspicuous as the last, as it needs to be sought after to be found.

The Orchis Family is well represented by twenty-nine species. Only a few are abundant. The Great Western White Orchis (*Habernaria leucophæa*) is found sparingly in all low lands. Its cream-white raceme of flowers are remarkable alike for their beauty and their delicious odor. The common Lady Slippers (*Cypripedium*) are abundant in some woodlands. *C. pubescens* is most frequently met with, and grows to a size rarely observed in the east.

The Iris Family is chiefly remarkable for the great number of individuals of one species, namely, the Blue-Eyed Grass (*Sisyrinchium Bermudiana*). When in bloom, it is observed everywhere on the prairies, because of the attractiveness of its numerous, tiny, star-like, blue and white flowers.

The Lily Family furnishes one of the earliest of our flowering plants, namely, the Dog's-Tooth Violets (*Erythronium*). *E.*

Americanum and *E. albidum* often make their appearance when snow still covers some of the hillsides. Three species of Lily grow wild, and the almost universal Solomon's seal. One of the most peculiar of all species is the so-called Soap Plant (*Yucca angustifolia*). It is exceedingly abundant in western Nebraska, and very rarely met with in the eastern counties. It contains a large amount of alkaline matter in its tissues, and hence its popular name, it frequently being used by "voyageurs," in the absence of soap, for washing. The plants do not bloom every year, but when a flower-stalk is produced it bears from a dozen to one hundred and twenty large, greenish, cream-colored, lily-like flowers. Its leaves are long, narrow, numerous and pointed.

Abundant among the plants of the State are the sedges. They bear such an external resemblance to the grasses that they are commonly confounded with them. There are at least one hundred and fifty-four species in the State, varying in size from forms only a few inches high, to flags, in ponds and sloughs, six feet high. They can generally be recognized by their three-cornered stems and solid culms, differing in this respect from the grasses, whose culms are round and hollow, or, at least, are not angled. As everywhere else, the genus Carex is represented by the most species, more than two-thirds of all in the State belonging to it.

The higher Cryptogamia (Flowerless Plants) are well represented in the State. Thirty-six species and varieties of ferns flourish in our woodlands. Four species of Lycopods are also met with. Over one hundred species of mosses have been identified. At least sixty-two species of lichens are scattered over the State. The Fresh Water Algae are exceeding abundant, and of these ninety-two species have been detected. In this department I have only skimmed the surface, but hope to renew my labors in this field, when many more will be added to the number of our species.

As some features of our flora have a special interest, I will discuss them more in detail in the following chapters.

CHAPTER VIII.

FOREST TREES AND SHRUBS OF NEBRASKA, WITH NOTES ON THEIR DISTRIBUTION.

IN the early reports on Nebraska it was represented that some half dozen species of forest trees were native here. Such reports were evidently made at random. It has too often happened that men with a respectable acquaintance with natural history felt competent to to describe the physical aspects and flora of a region after going through it on horse back at a gallop. Only after the most painstaking labor of fourteen years have I found many of the species contained in this list. Since my own catalogue of our Flora was published, and after I had given a list of our trees and shrubs to different parties for publication I discovered some additional species within our borders. One of these is the common white walnut or butternut (*Juglans cinerea*), that turned up in Dixon County, a few miles from Iona, in a woodland that I had frequently examined before. Simon Baltzley first informed me of its existence. I have no doubt that still more trees remain to be added to our Flora. There are so many sequestered canyons clothed with timber, which no botanist has yet visited, that it would be extraordinary indeed if some of them did not contain species as yet unknown in the State. I have shown elsewhere that in times quite recent, geologically, Nebraska was heavily timbered with a varied forest vegetation.* When the causes commenced to operate that finally reduced its area to present limits, some of the species retired gradually to such protected localities as favored their perpetuation. One of these causes probably was forest and prairie fires, inaugurated by primitive races, for the chase and for war. Some species are now confined to spots where fires cannot reach them. Another cause was probably the encroachment of the prairie on the timber area, caused by the ground being so compacted by the tread of countless numbers of buffaloes, that tramped out growing shoots,

*Chapter on Superficial Deposits of Nebraska.

and unfitting the soil for the burial, germination and growth of seeds. Since the buffalo has retired, and prairie fires are repressed, and rainfall is increasing, the area of timber lands is spontaneously extending again in many directions.

The following is my corrected list of our trees and shrubs. For the sake of convenience, the trees and shrubs are placed in separate lists, but the botanical order is preserved in both:

Forest Trees.

1. Papaw (*Asimina triloba.*) This species is generally a shrub in Nebraska, but I found a few in Richardson county that reached the dignity of small trees. Found only in southeastern Nebraska, and most abundant in Richardson County.

2. Linwood. Basswood. (*Tilia Americana.*) Most abundant along the bluffs of the Missouri. On the Elkhorn, Upper Loup, Nemaha, etc. Have seen it as far as the 102° meridian on the Niobrara, and on the Upper Republican. One of our native trees, most deserving of cultivation.

3. *Var. Pubesceus* of this species is found along the Missouri bluffs, south of the Platte, and on the lower Republican.

4. Hop Tree (*Ptelea trifoliata.*) Tree and shrub. Grows to the size of a small tree in St. John's timber in Dakota County. Found also on the Niobrara. Have not met with it south of the Platte.

5. Staghorn Sumach. (*Rhus typhina.*) Rare. Have seen only a few specimens in Dakota and Dixon Counties.

6. Ohio Buckeye (*Æsculus glabra.*) Occasional in southeast Nebraska. Most abundant on the Nemaha, and in Nemaha and Otoe Counties.

7. Sweet Buckeye (*A. flava.*) Rarer than the preceding, but has about the same range.

8. Sugar Maple (*Acer saccharinum.*) Rarely found native in Nebraska. I have only observed it in the Plyburg timber in Dakota County.

9. Silver Maple (*Acer dasycarpum.*) Rare in Nebraska. Found one growing during the last year, for the first time, on bottom near the borders of Cass and Otoe Counties.

10. Red Maple (*Acer rubrum.*) Abundant among other timber along most of our water courses.

11. Box Elder (*Negundo aceroides.*) One of the most abundant trees in the State. It grows largest and finest in northeast

Nebraska. Many trees of this species, near Ponca, are two feet in diameter, and from forty to fifty feet high. On the Missouri bottom, in the same section, they often grow in dense thickets. Is found to the west line of the State in south Nebraska, and to the 102° meridian along the Niobrara and its tributaries. Also on the Platte, in places, on the Elkhorn and the Loups. One of the easiest of our trees to propagate.

12. Red Bud. Judas Tree (*Cercis Canadensis.*) Common along the Missouri bluffs. Occasionally on the Platte, Republican, Elkhorn and Loup. Sometimes a shrub.

13. Coffee-Tree (*Gymnocladus Canadensis.*) Nowhere abundant. It is often met with in most of the larger timber belts of the State. I have found it of larger size and more frequently in Dixon and Dakota Counties than elsewhere in the State. I noticed a few near the mouth of Fairfield Creek on the Niobrara.

14. Honey Locust (*Gleditschia triacanthos.*) Common south of the Platte, but rare north. A few on the Loup and on the Republican.

15. Water Locust (*G. monosperma.*) Rare in Nebraska. Found only a few growing south of the Nemaha in Richardson County.

16. Wild Red Cherry (*Prunus Pennsylvanica.*) Southeastern Nebraska. Saw the finest in Richardson County. Grows there thirty feet high.

17. Wild Black Cherry (*P. serotina.*) Southeastern Nebraska, along the Missouri bluffs and on the Nemaha.

18. Choke Cherry (*P. Virginiana.*) Common along the Missouri bluffs, on the Republican, Nemaha, Niobrara and Loup. Only occasionally reaches the dimensions of a tree; generally a shrub.

19. Scarlet Fruited Thorn (*Cratægus coccinea.*) Tree small. As frequently a shrub as tree. Widely spread over Nebraska wherever there is timber, but nowhere abundant. In the form of a tree it formerly could be frequently found along the Missouri timbered bluffs, from the Omaha Agency to the north line of the State.

20. Black Thorn (*C. tomentosa.*) A low tree, but often a mere shrub. It exists of tree size on the middle Niobrara.

21. White Ash (*Fraxinus Americana.*) Grows in northeast Nebraska to a magnificent size, and is comparatively abundant.

Found in less numbers south of the Platte. Have seen it near the west line of the State, on the Arickaree, and on the Niobrara as far as the 101° meridian. Also found on the Elkhorn and the Loup and Blue Rivers.

22. Red Ash (*F. pubescens.*) Very rare in eastern Nebraska. Have met with it sparingly on the Republican, Arickaree, and on the Niobrara. Occasionally found on the Elkhorn and Loup.

23. Green Ash (*F. viridis.*) Medium sized. Common in eastern Nebraska. Found a few in southwestern Nebraska, on the Arickaree, on the Niobrara, Loup, Elkhorn ank Bazile.

24. Black Ash (*F. sambucifolia.*) Rare. Found it for the first time during the last few years near the Nemaha, in Richardson County.

25. Blue Ash (*F. quadrangulata.*) Tree here of medium size. Next to White Ash in abundance. Most frequently found in southeastern Nebraska. I have seen a few of them on the Republican, Elkhorn, Loup and Niobrara.

26. Slippery or Red Elm (*Ulmus fulva.*) Found widely spread, but nowhere very abundant over eastern Nebraska. It is apt to be met with in timber belts along water courses. It is met with at intervals along the Republican, Nemaha, Elkhorn, and on the Niobrara.

27. White Elm (*U. Americana.*) Same localities in the main as the last, but more abundant.

28. Cork White Elm (*U. racemosa.*) A few in Dakota and Dixon Counties. Still more rarely met with in Cass, Otoe and Nemaha Counties. Found a few on the Niobrara, east of the mouth of the Snake river. A fine specimen on Mr. Master's grounds, a few miles east of Nebraska City.

29. Wahoo Elm (*U. alata.*) Rarest of all our elms. Have only seen three specimens in Nebraska—one in Cass and two in Richardson County.

30. Hackberry (*Celtis occidentalis.*) Common in eastern Nebraska. It is sparingly represented on the Republican, is more abundant on the Niobrara. A few are also found on the Elkhorn and the Loups.

31. Red Mulberry (*Morus rubra.*) Found sparingly all along eastern Nebraska, and generally on the timbered bluffs of the Missouri. The finest trees occur in Dakota and Dixon counties. It also occurs on the Niobrara as far west as the 101st meridian.

32. White Mulberry (*M. alba.*) This species is supposed to be a foreigner introduced into the State. As I have some doubts about this, I give it a place in this list. Have only found it on the Missouri bluffs, southwest from Dakota City.

33. Buttonwood (*Platanus occidentalis.*) Have found it only in Cass, Otoe, Nemaha and Richardson Counties. Most abundant in Otoe. The bottoms of the Missouri afford it a congenial home, and here it flourishes. In some groves it has excluded most other forms.

34. Butternut (*Juglans cinerea.*) Rare in Nebraska. Know of but one tree native to the State. This was first found by Simon Baltzley, Esq., near Ionia, in Dixon County, on the Missouri bottom, near the bluffs.

35. Black Walnut (*J. nigra.*) On the whole the most valuable of our native trees. It was formerly quite abundant in eastern Nebraska. Owing to the high price of the lumber, millions of feet have been shipped away, the bulk of it going to St. Louis. In 1865 and 1866 a half million feet of lumber was taken from Dakota County alone. In Dakota and Dixon Counties there are yet some of these Black Walnuts standing, forty feet without a limb, and from three to five feet in diameter. They are found on the Republican, on the Loup, and on the Niobrara and Elkhorn. When raised from the seed, and not transplanted, they are comparatively fast growing. One of the most desirable trees for cultivation.

36. Shell Bark Hickory (*Carya alba.*) Found, at long intervals, in southeastern Nebraska, and still more rarely north of the Platte.

37. White-heart Hickory (*C. tomentosa.*) Have only seen a few of this species, in Richardson and Nemaha Counties.

38. Pignut Hickory (*C. porcina.*) Mostly in northeastern Nebraska, and on the Niobrara.

39. Butternut Hickory (*C. amara.*) Our commonest species. Have observed it sparingly in every county along the Missouri, and also at long intervals on the Republican and Elkhorn. Often these hickories only reach the dimensions of shrubs.

40. Burr Oak (*Quercus macrocarpa.*) Our most abundant species of oak. Found all along the Missouri, on the Niobrara and its tributaries, as far as to the 102d meridian, on the Elkhorn, the Upper Loups, on the Nemaha, Republican, etc.

41. *Var. Olivæ formis*, of the above, is found principally in northeast Nebraska

42. Post Oak (*Q. obtusiloba.*) Sparingly on the Elkhorn and Niobrara.

43. White Oak. Variety of. (*Q. alba. Var. Gunnisonii.*) Rather abundant in some of the canyons leading into the middle course of the Niobrara, also a few on the Upper Loup. Rare in eastern Nebraska.

44. Yellow Chestnut Oak (*Q. primus. Var. acuminata.*) Southeastern Nebraska; occurs sparingly.

45. Swamp White Oak (*Q. bicolor.*) Most abundant in timbered bottoms and edge of bluffs, in northeast Nebraska and on the Niobrara. More sparingly represented south of the Platte, in the counties bordering on the Missouri.

46. Yellow Chestnut Oak (*Q. castanea.*) Southeastern Nebraska. Sparingly on the upper Niobrara.

47. Dwarf Chestnut Oak (*Q. prinoides.*) Though this is a shrub, it in exceptional cases grows to the size of a small tree. Eastern Nebraska, Elkhorn, Nemaha and the Niobrara.

48. Black Jack Oak (*Q. nigra.*) Occurs sparingly in southeastern Nebraska, and most abundantly in Richardson County. A few in northeast Nebraska. on the Niobrara and Elkhorn.

49. Scarlet Oak (*Q. coccinea.*) Occurs sparingly along the Missouri, on the Nemaha, Elkhorn and Niobrara.

50. *Var. tinctoria* of the above is a rarer form. I have obtained it only from Otoe County, through Mr. Masters.

31. Red Oak (*Q. rubra.*) Found on the Niobrara, Bazile, Missouri, Elkhorn and the Nemaha, but nowhere in large quantities.

52. Swamp or Pine Oak (*Q. palustrus*). Have only found it on the Missouri bluffs and between north of the Platte and on the Niobrara.

53. Iron Wood (*Carpinus Americana*). Very sparingly represented in most of the eastern woodlands of the State. Most abundant in Northeastern Nebraska.

54. Paper Birch (*Betula papyracea*). Only occasionally represented along the wooded bluffs bordering the Missouri bottoms. Found it once on the Niobrara, near the mouth of Rapid Creek.

55. Red Birch (*B. nigra*). Rare in Nebraska. Found my first and only specimen three years ago, on the timbered bluffs in southern part of Dakota County.

56. Glaucous Willow (*Salix discolor*). Generally a shrub, but on the Missouri bottoms and on Willow Creek, a tributary of the Republican, sometimes becomes a small tree. Is widely spread over the State.

57. Long-headed Willow (*S. rostrata*). This generally a shrub, but often reaches the dimensions of a tree on the Missouri bottoms, and especially in the St. John's timber in Dakota County. Found on the Niobrara, Republican and Loup.

58. Black Willow (*S. nigra*). Abundant on the Missouri bottoms in a few localities. Largest trees occur in St. John's timber in Dakota. It is also found on the Republican, on Willow Creek, Nemaha, Elkhorn, Loup and Niobrara.

59. Shining Willow (*S. lucida*). Generally a shrub, but on the islands of the Platte and low Missouri bottoms it often reaches the size of a small tree. Found also on the Elkhorn, Republican, Loup and Niobrara.

60. Long Silver-leaved Willow. (*S. longifolia var-argophylla*). Also generally a shrub, but is found of tree size in St. John's timber, in Dakota County. It is also found on the Loup and Southeastern Nebraska.

61. American Aspen (*Populus tremuloides.*) I found this species within our western border, only during the last few years. On Upper Republican, North Branch of Platte and Niobrara.

62. Cottonwood (*P. monilifera.*) This is the most widely spread and abundant tree in the State, being found, with few exceptions, on our western and northern border, wherever trees grow at all. It apparently does equally well on upland or bottom. It constitutes extensive forests on some of the Missouri bottoms. Some trees in the St. John's timber, in Dakota County, five feet in diameter at the butt, were over three hundred years old, as that was the number of rings that were counted on them.

63. Angled Cottonwood (*P. angulata.*) Rare. Found only in northeast Nebraska.

64. Balsam Poplar (*P. balsamifera.*) Have found it only in Cedar County, and on the Niobrara.

65. *Var. Candicans* of the above have found only on the middle Niobrara.

66. Western Yellow Pine (*Pinus ponderosa.*) Canyons and low bluffs in western Nebraska and on the Niobrara.

67. *Pinus flexilis.* Rare. Fonnd a few growing northwest and southwest of Sidney, and finer ones on the Niobrara.

68. Engleman Spruce (*Abies Englemanii.*) Have found it only on the Niobrara and tributaries.

69. Douglass Spruce (*Abies Douglassii.*) On the Niobrara and its tributaries.

70. White Cedar (*Cupressus thyoides.*) Northeast Nebraska, along the Missouri and on the Niobrara.

71. Red Cedar (*Juniperus Virginiana.*) Generally scattered over the State where timber occupies bluff lands or dry bottoms, but abundant only in a few localities in northeast Nebraska, on the Niobrara, and on the Loup. Extensive groves occur on the Loups and their tributaries, and on the Niobrara and its tributaries. It is one of the most hardy and most easy to cultivate of all our evergreens. A slow grower, it is still a most desirable tree, because of its great hardiness, and when trimmed into shape, of great beauty.

After subtracting from the foregoing list ten kinds that are as frequently shrubs as trees, the number of species and varieties that are left is still sixty-one. In the St. John's timber, in Dakota County, and at the edge of the bluffs, I once on the space of two acres counted eighteen species of the trees included in this list. Facts like these demonstrate the great adaptation of Nebraska to the growth of forests. A little assistance from man, and nature will again gradually clothe a large part of the plains with a covering of timber.

Shrubs.

1. Papaw (*Asimina triloba.*) Southeastern Nebraska. Sometimes becomes a small tree.

2. Creeping Barberry (*Berberis repens.*) On Loup and Niobrara. One foot high in the mountains; here from one to two feet high.

3. Downy Hudsonia (*Hudsonia tomentosa.*) In counties bordering the Missouri, and occasionally in Johnson, Lancaster and Saunders. Everywhere rather rare.

4. Shrubby St. John's Wort (*Hypericum prolificum.*) Have seen it only on south side of the Nemaha in Richardson County.

5. Naked Clustered St. John's Wort (*H. nudiflarum.*) Widely spread over eastern Nebraska, but nowhere abundant. Have seen it on the Republican, on Wood River and the Elkhorn.

6. Prickley Ash (*Zanthaxylum Americanum.*) Along the Missouri, Niobrara, Blue, Republican, etc.

7. Hop Tree (*Ptelea trifoliata.*) Only found a few specimens in Dakota and Dixon Counties, and on the Niobrara.

8. Smooth Sumach (*Rhus glabra.*) Common in Nebraska.

9. Dwarf Sumach (*R. copallina.*) Only met with at long intervals in the eastern counties.

10. Fragrant Sumach (*R. aromatica.*) Have found this only on the Niobrara.

11. Alder-leaved Buckthorn (*Rhamnus alnifolius.*) Have only met it at long intervals in northeastern Nebraska.

12. New Jersey Tea (*Ceanothus Americanus.*) Common.

13. Dwarf Redroot (*C. ovalis.*) Widely dispersed as the foregoing, but not so abundant.

14. Climbing Bitter Sweet (*Celastrus scandens.*) Common in woodlands. Have seen it as far west as 101° meridian.

15. Spindle Tree (*Euonymus atropurpureus.*) Only occasionally found on the borders of timber belts.

16. Strawberry Bush (*E. Americanus.*) Rarer than the preceding, but found at long intervals over the greater part of eastern Nebraska.

17. *Var. obovatus* of the preceding, I found only in Dakota County.

18. American Bladder Nut (*Staphylea trifolia.*) Common along the Missouri bluffs, on the Nemaha. Occasionally on the Blues and on the Niobrara.

19. False Indigo (*Amorpho fruticosa.*) Common along all our principal water courses.

20. Yellow or Red Plum (*Prunus Americana.*) Found in the thickets in and bordering timber belts, in canyons, draws and narrow valleys in almost every county in the State. In many places very abundant.

21. Chickasaw Plums (*P. chicasa.*) Same distribution as the preceding.

22. Dwarf Cherry—Sand Hill Cherry (*P. Pumilla.*) Found most abundantly in central and western Nebraska, on sand hills and on sandy land.

23. Choke Cherry (*P. Virginiana.*) Found all along the Missouri, on the Niobrara, Platte, Nemaha, and in places on the Republican. Sometimes becomes a small tree.

24. Nine Bark (*Spiræa apulifolia.*) This shrub grows from four to six feet high. On the Niobrara, and rarely in eastern Nebraska.

25. *Var. parvifolia* occurs only rarely, on the Niobrara.

26. Meadow Sweet (*S. salicifolia.*) On low grounds in eastern Nebraska. Have seen most in Dakota County.

27. *Cercocarpus parvifolius.* Diffusely branches from the ground, with tomentose leaves six to eight lines long. Have found it only on the Niobrara.

28. Scarlet Fruited Thorn (*Crataegus coccinea.*) This sometimes becomes a small tree. Not abundant, but widely spread in woodlands over eastern Nebraska.

29. Black Thorn (*C. tomentosa.*) Sometimes a low tree. Most abundant along the Missouri and on the Niobrara. Found at longer distances on the Blue, Republican, Elkhorn and Loup.

30. *Var molis* of the above I have seen only once on the Republican.

31. June Berry (*Amelanchier Canadensis.*) Frequently met with in woodlands over eastern Nebraska, on the Republican, Elkhorn, and quite abundant on the Niobrara.

32. *Var. Botrychium.* Only on the Niobrara.

33. *Var. Ablongifolia.* Quite small. Southeast Nebraska.

34. *Var. Alnifolia.* More abundant than the type form, and in the same localities.

35. Climbing Prairie Rose (*Rosa satigera.*) Northeastern Nebraska. Have found the most in Dakota County.

36. Swamp Rose (*R. Carolina.*) Most abundant in Northeastern Nebraska, and rare south of the Platte.

37. Dwarf Wild Rose (*R. lucida.*) Abundant everywhere.

38. Early Wild Rose (*R. blanda.*) Found all over the State.

39. Wild Gooseberry (*Ribis cynosbati.*) Northeastern Nebraska, and on the Niobrara.

40. Smooth Wild Gooseberry (*R. Rotundifolium.*) Common all over Nebraska, in woodlands, sheltered valleys, canyons and draws.

41. Swamp Gooseberry (*R. lacustre.*) Abundant along the Missouri bottoms and in spots on the Nemaha, Platte, Elkhorn, Loup and Republican.

42. Smooth Wild Gooseberry (*R. hirtellum.*) Common in most woodlands in Nebraska. Many forms of gooseberry have not yet been reduced to order. They grow here with an exceptional luxuriance. See chapter on Wild Fruits.

43. Wild Black Currant (*R. floridum.*) Occasionally found on

the Missouri bottoms and its tributaries, and on the Republican. Most abundant on the Niobrara.

44. Missouri Currant (*R. aureum.*) Rare in southeast Nebraska. On the Loup and the Niobrara, and occasionally on the Elkhorn.

45. Dwarf Cornel (*Cornus Canadensis.*) This barely a shrub. Stem mostly subterranean, and only five or six inches above ground. On the Niobrara.

46. Round Leafed Cornel (*C. circinnata.*) Occurs sparingly in most of the woodlands in eastern Nebraska, on the Republican, and more abundantly on the Niobrara.

47. Kinnikinnick (*C. sericea.*) More abundant than the last. Found in most of the woodlands of the State.

48. Red-osier Dogwood (*C. stolonifera.*) Most abundant in the timber belts and their borders in northeastern Nebraska, and on the Niobrara. Rare in south Nebraska.

49. Rough-leaved Dogwood (*C. asperifolia.*) Sparingly in timber belts in southeast Nebraska. Have only met it in Dakota and Cedar counties in north Nebraska.

50. Panicled Cornel (*C. paniculata.*) Rare. Only found a few on the Niobrara.

51. Alternate-leaved Cornel (*C. alternifolia.*) Rare. Only in northeastern Nebraska.

52. *Cornus pubesceus.* North branch of the Platte, and on the Niobrara.

53. Wolfberry (*Symphoricarpus occidentalis.*) Common in timber belts and their borders.

54. Snowberry (*S. racemosus.*) Common on the prairies and borders of woodlands.

55. *Var. parciflorus* of the above mostly in southeastern Nebraska.

56. American Woodbine (*Lonicera grata.*) Rare. Only in northeast Nebraska.

57. Yellow Honeysuckle (*L. flava.*) Rather abundant. Have seen it on the Niobrara as far west as 102° meridian, and on the Republican as far west as the Arickaree. Lines the sides of wooded bluffs and their borders.

58. Hairy Honeysuckle (*L. hirsuta.*) Rare. Have only observed it once on the side of a bluff above Ponca, and once near the Yellow-banks on the Elkhorn.

59. *L. involucrata.* On the North Platte and on the Niobrara.

60. Bush Honeysuckle (*Diervilla trifida.*) Counties on the Missouri, north of the Platte and on the Niobrara.

61. Elder (*Sambucus Canadensis.*) Sometimes is here ten feet high. Common and abundant.

62. Red-berried Elder (*S. pubens.*) Rare. Have seen it only on the Niobrara.

63. Maple-leaved Arrow-wood (*Viburnum acerifolium.*) Have seen it only on the Niobrara.

64. *Var. pauciflorum.* Extreme western Nebraska, and the Niobrara. Rare.

65. Button Bush (*Cephalanthus occidentalis.*) Sparingly in eastern Nebraska, along the Missouri.

66. Small Cranberry (*Vaccinium oxycoccus.*) In bogs at the head waters of the Loups and their tributaries. Four to nine feet high.

67. Dwarf Bilberry (*V. caespitosum.*) Rarely met with in northeast Nebraska, and on the Niobrara.

68. Bearberry (*Archtostaphylos Uva-ursi.*) In the middle Niobrara region.

69. Canadian Sheperdia (*Sheperdia Canadensis.*) On the Niobrara.

70. Buffalo Berry (*S. argentea.*) Common in northeastern Nebraska, in most timber belts, especially on the Missouri bottoms, and on the Platte. Is very abundant on the Republican, and in places almost to the west line of the State. On the Elkhorn and Loups. Abundant on the Niobrara. Deserves cultivation for its beauty, hardihood and fruit. Grows sometimes into a small tree.

71. Dwarf Chestnut Oak (*Quercus prinoides.*) On the Missouri bottoms and edge of bluffs. Nemaha, Elkhorn, and on the Niobrara.

72. Beaked Hazelnut (*Corylus rostrata.*) Northern and northeastern Nebraska.

73. Wild Hazelnut (*C. Americana.*) Abundant and widely distributed. Along almost the whole length of the Niobrara, on the Elkhorn, Missouri bluffs, Platte, Loups and Republican.

74. Sweet Gale (*Myrica gale.*) In Dakota, Dixon and Cedar counties, and on the lower Niobrara.

75. Sweet Fern (*Comptonia asplenifolia.*) Found occasionally on the sides of bluffs over eastern Nebraska.

76. Low Birch (*Betula pumilla.*) Found rather frequently in most of the timber belts on the Missouri, Nemaha and Niobrara.

77. Western Birch (*B. occidentallis.*) Have found it only on the Niobrara.

78. Green Alder (*Alnus viridis.*) Have found it only on the Niobrara.

79. Speckled Alder (*A. incana.*) Sparingly in Northeastern Nebraska.

80. Smooth Alder (*A. serrulata.*) Rare in eastern Nebraska. Have only found half a dozen specimens along the counties on the Missouri.

81. Hoary Willow (*Salix candida.*) Common in low situations over the greater part of Nebraska.

82. Dwarf Gray Willow (*S. tristis.*) In eastern Nebraska; most abundant north of the Platte, and especially on the Niobrara. Rarely on the Republican.

83. Bush Willow (*S. humilis.*) Missouri bottoms, Niobrara. Loups, Elkhorn, Logan, Platte and Republican.

84. Glaucous Willow (*S. discolor.*) Sometimes a small tree. Republican River, Willow Creek, Loups, Elkhorn, and Missouri bottoms.

85. Heart-leaved Willow (*S. cordata.*) Lower Niobrara, Platte, Nemaha, Republican, and occasionally on the Missouri bottoms.

86. Narrow-leaved Willow (*S. angustata.*) Common over the State. Have observed it on the west line of the State on the Republican and Niobrara. On Loups, Elkhorn, etc.

87. Long Beaked Willow (*S. rostrata.*) Habital same as the preceding. Often a small tree.

88. Shining Willow (*S. lucida.*) Low bottoms in eastern and northern Nebraska, and on some of the tributaries of the Republican.

89. Long Silver-leaved Willow (*S. longifolia, var. argophylla.*) Mostly a shrub, but sometimes becomes a tree. Loup Rivers, Niobrara, Republican and Missouri.

90. Stalk-fruited Willow (*S. pedicellaris.*) On the Niobrara.

91. Common Juniper (*Juniperus communis.*) Missouri River, counties north of the Platte, and the Niobrara.

CHAPTER IX.

THE WILD FRUITS OF NEBRASKA.

PLUMS.—Prunus Americana.—Its appearance, habits, abundance, and qualities.—P. Chicasa.—Hybrids.—A late variety.—Cultivation.—Stock for grafting peaches, plums, and apricots.—Hardiness.—The Curculio.—P. Pumila, or sand-hill cherry.—P. Pennsylvanic.—P. Virginica.—STRAWBERRIES.—Fragaria vesca.—Delicious and abundant.—F. Virginiana.—RASPBERRIES.—Rubus Occidentalis.—R. Triflorus.—R. Strigosus.—R. Villosus.—HAWTHORNS.—Cratægus tomentosa.—C. Malis.—JUNE BERRIES.—Amalanchier Canadensis.—A. Alinifolia.—WILD CURRANTS AND GOOSEBERRIES.—Ribes Hirtellum.—R. Rotundifolium.—R. Lacustre.—R. Cynosbati.—R. Floridum.—GRAPES.—Vitis æstivalis.—V. Cordifolia.—Re-classification and hybrids.—Wine.—THE MULBERRY. — THE BUFFALO BERRY.— Shepherdia Argentia.—THE ELDERBERRY. — THE PAPAW. — Asimina triloba.—NUTS. — Juglans nigra.—Carya Alba.—Corylus Americanus.

WILD fruits are a prominent feature of Nebraska. They luxuriate in its rich soil and almost semi-tropical summers. Among the wild fruits of this State the plum family is a remarkable example of how nature herself sometimes ameliorates and improves her original productions.

There are three type species of plums in the State, namely, *Prunus Americana*, *P. chicasa*, and *P. pumila.* Of these there is an almost endless number of varieties. In a plum thicket in Dakota County, covering only a few acres, I counted, while in fruit, nineteen varieties of *Prunus Americana* and *P. chicasa,* varying in size from a fourth to an inch and a quarter in diameter, and in color from almost white and salmon, to many shades of yellow, tinged with green and red, and from a light, dark, and scarlet red, to purple tinged with different shades of yellow. Such instances are frequent over most portions of the State, the plums being common in almost every county, especially along the water courses, and bordering the belts of timber. These plum groves in spring time present a vast sea of flowers, whose fragrance is wafted for miles, and whose beauty attracts every eye. The varieties of the *Prunus*

Americana have oval or obovate leaves (broader at the tip than where the stem is attached), with saw-toothed or doubly saw-toothed edges and very full of veins. The fruit is globular or oval, and ranges from a half-inch to an inch and a quarter in diameter., the latter being an exceptionally large size. The color is all shades of yellow, with some red and crimson. Its juice is pleasant, but its skin is tough and acerb; and its stone is sharp edged or margined. The shrub varies in height from six to twenty-five feet. The fruit ripens in August and the first half of September. These are the prevailing characters, but they vary greatly, some of the varieties producing fruit which is a great improvement in size and taste on the type species, while others again have deteriorated. Nearly all the varieties part readily from the stone.

Still more subject to change is the *Prunus chicasa*, which grows from four to twelve feet in height, sometimes thorny, and always with long, narrow, almost lance-shaped, acute leaves, whose edges are set with very fine teeth. The fruit is globular, of all shades of red, and from half an inch to an inch or more in diameter, of pleasant (some varieties, of delicious) flavor, thin-skinned, and containing an almost round and entirely marginless stone. Most of the varieties of this plum do not part readily from the stone. The fruit ripens the latter part of July and in August.

I have found many forms that cannot be readily classed with either of these species, but seem to be a cross between the two. In fact these plums often hybridize. This is not strange where both species often grow together in such compact thickets that it is difficult to penetrate them. When the pollen of the one is carried to the pistils of the other species the young plants that come from the seeds must exhibit some characters which are common to both.

One variety of the *Prunus Americana*, that grows from six to ten feet in height, and has greenish white fruit, occasionally tinged with yellow, rarely ripens its fruit. I have seen its fruit hard and green towards the end of October; but when plucked, even then, and stowed away in an empty room, it readily ripens, like pears when similarly treated. Occasionally a tree is found producing a little round red plum, slightly larger than a morella cherry, which bears double fruit.

Delicious as some of these wild plums are, their size and flavor are much improved by cultivation and pruning. It is easy to pro-

duce an early and fruitful grove of these plums from the seed. A tree grown in my former grounds in Dakota City yielded thirty-nine blossoms the second year from the seed, and seven hundred and ninety the third year. It is also found that these wild plums are magnificent stock on which to graft the peach, other varieties of plums, and the apricot. Their great hardiness, and the readiness with which they unite with the old cultivated plums, makes them invaluable to those who raise such fruit.

Alas! there is one drawback to this picture. The everlasting enemy of the plum, the curculio,* is also present. The young fruit sets each year by the million, but some of the finest groves are sometimes for years in succession prevented by this cause from bearing much fruit. Yet so great is the vitality of the plum family in this State that some varieties will succeed even in despite of the curculio. One such grove I found years ago along the bluffs southwest of Dakota City. The trees were laden with fruit even when all the other groves in the neighborhood were almost entirely shorn of their treasures. The foliage indicated a hybrid between the two species under consideration, at least it possessed some characteristics that belonged to these two separately, along with others of its own. The fruit was large for wild plums, the skin tough, though comparatively thin, and could readily be pared. The flesh was hard and acid until it was fully ripe, when it became juicy and melting. I have no doubt varieties of this kind could be selected from these ample stores of nature which would be of incalculable value to the horticulturist.

The dwarf or sand-hill cherry, so famous on our western plains, is really botanically a dwarf plum, (*Prunus pumila*)—and therefore we speak of it last. The stem is smooth, depressed, trailing or semi-erect, from eight to twenty-four inches high. The leaves are obovate lanceolate, tapering to the base, sometimes a little toothed towards the apex, and pale underneath; the flowers numerous, two to four in a cluster. The fruit varies greatly, but is generally about half an inch long and three-eighths broad, ovoid, dark purple, brown purple, brown, reddish, or nearly black, generally sweet, sometimes delicious and occasionally almost insipid. It is enormously productive. The shrub has a spreading habit, forming dense masses, sometimes covering from thirty to sixty

* *Conotrachelus nenuphar*, commonly spoken of as the "plum weevil."

square feet of ground, but usually the tufts are not more than fifteen to twenty-five feet in area. It suckers abundantly from the roots, and propagates in this way as well as by seeds. It is found over the greater part of the western half of the State, and while it is not excluded from the richest soil if dry, it seems to be partial to sandy localities, rich in alkaline earths. As this plum is nearly related to some of our cultivated varieties of cherries, and the stamens and pistils of the flowers are large in both, it will require no great skill to produce a cross between them. And as Fuller has remarked ("Small Fruit Culturist"), a cross between the dwarf plum and a Bigarreau or Morella variety, retaining the dwarf habit, vigor, and productiveness of the former, with the flavor of the latter, would be an acquisition of incalculable value, and would completely revolutionize cherry culture. However this may be, the best varieties of the dwarf cherry are valuable as they come from the hand of nature. Many an explorer and traveler in the unsettled regions has been refreshed by them, and the day is not distant when this fruit will, as it deserves to, have a place in the gardens of all the people.

Three species of wild cherries grow in various parts of the State. The wild red cherry, (*Prunus Pennsylvanica*), grows sometimes to the dimensions of a small tree. Its leaves are oblong, lanceolate, pointed, margins finely saw-toothed, green on both sides, flowers on long stems, and the fruit of a light red color, sour, very small and of little merit. The wild black cherry, (*Prunus seritina*), is valuable only for its wood, which is close grained, reddish or brownish, and highly esteemed by the cabinet maker for the high polish of which it is capable. The lance oblong, smooth leaves are taper pointed, glandular and saw-toothed. The flowers are produced in long clusters (*racemes*); its fruit is reddish or purplish black, ripening in autumn. Though the fruit is not sought after by human beings, it is eagerly devoured by birds. The bark is a remarkable tonic. I have only noticed the tree in the southeastern part of the State.

The choke cherry (*Prunus Virginica*), is a tall shrub with greyish bark, oval, oblong, or obovate and abruptly pointed thin leaves, very slender, sharp saw-toothed, and from two to three inches long. The flowers are in a short close cluster. The fruit ripens in summer, and is of a dark red color, and very astringent to the taste, but rather agreeable.

STRAWBERRIES.

Two species and one variety of strawberries, with endless modifications, are common all over Eastern Nebraska. They flourish on the sides of the bluffs, and at the edge of timber belts, from which they creep far out on the prairies. Perhaps the commonest strawberry is *Fragaria vesca*, which has produced the Alpine, Wood, Perpetual, and many other varieties. Here it is mostly slender, with thin dull leaves, strongly marked by the veins, calyx open or reflexed after flowering; and fruit inclined to be conical or elongated, much like the so-called lady finger, and fully as large and high scented. The runners often creep several feet. This strawberry varies so much that I have often been unable to distinguish it from the *Fragaria Virginiana* except by one character, its seeds (*akenes*), which are always superficial, and seem to stick out of the berry. So abundant is this fruit in some seasons that the ground in its favorite retreats seems absolutely red with it. Once when making a survey of some timber lands in Dakota County, on a sultry July day, and almost exhausted by the heat and from thirst, I unexpectedly came to a patch of these berries in an opening of the woods. Never before was I so grateful for fruit, and fruit that was delicious enough to adorn the finest tables in Christendom. As already intimated, this species is the most variable of all the strawberries. It is found all over Europe and in all the high and on many of the low lands of North America. Its tendency to become everbearing, so strikingly exemplified elsewhere, is also characteristic of it in many places in Nebraska. I have noticed localities where it produced a succession of ripe berries for two months.

The other species common to this State is *Fragaria Virginiana.* It is the original of the American scarlet and innumerable other varieties. It can be distinguished from the former by the seeds (*akenes*) being sunk in the flesh of the berry. Its runners are seldom over a foot long. Its flowers however are staminate, that is, its male and female organs are on different plants. There is an insensible gradation between this species and the *variety Illinoiensis* of Gray, which is coarser and larger, and the hairs which are scattered over it, especially on the flower stock, are rougher. The strawberries of Nebraska need to be thoroughly examined. Certainly where there is such a tendency shown to varieties and improvement, some of the most promising, under the skillful treatment of the gardener, would become permanent additions to our list of desirable small fruits.

Raspberries

are represented in Nebraska by three species. A black raspberry, a variety of *Rubus occidentalis*, is common in every county. It is a profuse bearer, and the fruit is nearly a third larger than the American blackcap. It is most abundant along streams and in woodlands and their borders. Where it is cultivated the canes make a much stronger growth than in their native wilds, though even there some varieties seem equal to any produced in gardens. A dwarf raspberry, (*Rubus triflorus*,) and the wild red, (*Rubus strigosus*,) were sent to me in flower during the past season from the western part of the State, previous to which I was not aware that they existed within our borders. They have not yet been found in the eastern part of the State.

Blackberries.

Of these only one species has yet been found in the State. This is the high blackberry, (*Rubus villosus*). It is rather abundant along some of the streams and timber belts in the southeastern part of the State. Wherever this wild variety is transplanted into gardens and cultivated, it bears large quantities of delicious fruit.

Hawthorns.

Though unimportant as fruits the hawthorns should not be overlooked by the amateur horticulturist. The blackthorn (*Cratægus tomentosa*), and its variety *malis*, are most abundant. It is a shrub or small tree from six to twenty-five feet in height. The leaves are oval, abrupt at the base, margins sharply saw-toothed or cut into many small lobes, and downy beneath, especially when young. The flowers are compacted into clusters (*corymbs*) of from six to thirty flowerlets in a bunch. The fruit is scarlet or orange, from two-thirds to three-fourths of an inch long and rather pleasant to the taste. The fruit of the variety *malis* is dull red and more insipid. Though not esteemed by man, the fruit is eagerly sought after by prairie chickens and quail. I have seen hundreds of these wild fowl at one time feasting on this fruit, which they seemed to prefer in its season to all other food.

The June Berry.

This fruit is abundant in some portions of Nebraska. It is a small tree or shrub, from ten to thirty-five feet in height. There are apparently three or four species, but they run so much into each other,

that botanists as yet treat them as one species with many varieties. It is known as *Amelanchier Canadensis*. The variety most common here is *Alinifolia*, with roundish, blunt leaves, which are toothed towards the summit. The flowers, which are white, are produced in long loose clusters (*racemes*). Berry purplish, sweet, and generally deliciously-flavored. This berry has always been a favorite with the Indians. They dry and mix it with pemican (*preserved meats*), to which it gives a delicious flavor. Nothing is supposed to give more daintiness to an Indian feast than June berries boiled in the broth of fat meat. Children of every age equal the Indians in their admiration and enjoyment of June berries. It would "pay" to cultivate them for "the litttle ones" alone.

Wild Currants and Gooseberries.

There are four species of gooseberries growing wild in the State. One of these, a "Smooth Wild Gooseberry" (*Ribes hirtellum*), has smooth stems, short thorns, or none, and smooth, small, purple, and sweet berries. It is not very abundant. Another "Smooth Wild Gooseberry" (*R. rotundifolium*), in its many varieties, is met with constantly, especially in the timber and along our streams, and is a most abundant bearer. The leaves are nearly smooth, roundish, three to five lobed and truncate at the base; stems slender and from one to three flowered. It grows from two to four feet high, the stems having whitish bark. One variety of this species bears a berry, long, large, and green. Another variety, which grows from three to four feet high, sets its canes thickly, and they are covered with slim thorns of a brownish, purplish color. The fruit is as large as a Houghton, sometimes larger, somewhat veined, and of a clear, glossy, transparent color, oval or round, and sometimely slightly flattened at the ends, and with a rich vinous flavor. I have found a few specimens three-fourths of an inch in diameter when ripe, and never observed them to be affected with mildew. So abundant are they that the Indians often pick many bushels per day for weeks in succession and carry them to the various markets. They bear transportation well. Many citizens are now well supplied with these berries from stocks transplanted from the woods into their own grounds. I have myself planted the Houghton in a row alongside of this wild variety, and the latter proved superior in productiveness and hardiness to the former. The Swamp Gooseberry (*R. lacustre*), whose young stems are clothed with bristly

prickles, and small weak thorns, and whose leaves are heart-shaped, and from three to five parted, and the lobes cut, and whose fruit is bristly, small, and disagreeable, is unimportant. Even birds generally give it a wide berth. The "Wild Gooseberry" (*R. Cynosbati*), with pubescent leaves, slender peduncles and spines, and a large berry armed with long bur-like prickles, is no better than the last. In a few localities it is quite abundant.

Two species of wild currants abound. The "Wild Black Currant" (*R. floridum*) is remarkable for its large flowers. The leaves are from five to seven-lobed, doubly saw-toothed, and generally sprinkled with resinous dots, slightly heart-shaped, and the racemes are downy, drooping; the fruit is round-ovoid, black and smooth, and in smell and flavor much like the black currant of the garden The Buffalo or Missouri currant also abounds in many localities. It is remarkable for the spicy fragrance of its yellow blossoms, and is often cultivated for ornament. Its fruit is of little or no value.

Black Haws.

Recently the Black Haws (*Viburnum Prunifolium*) have turned up in Nebraska. They escaped my notice until my attention was directed to them by J. Gillman Esq., of Otoe County. The leaves and fruit have since been sent to me. They are found in some of the timber belts of Otoe, Cass, and Nemaha counties. Though not specially sought after for its fruit except by birds, its broadly oval leaves, its beautiful form and flowers make it a desirable tree to give variety to cultivated grounds.

Grapes.

Two species of grapes, with a great number of hybrids and varieties, abound in Nebraska. It is hard to realize without seeing it, with what luxuriance the vine grows in this State. Some of the timber belts are almost impassible from the number and length of the vines, which form a network from tree to tree. Straggling vines are sometimes found far out on the prairies. Where deprived of any other support they creep along the ground and over weeds and grass. The Summer Grape (*Vitis œstivalis*) can generally be recognized by the downy character of its young leaves, which are smooth when old. They are simple, rounded, heart-shaped, and often variously lobed. The panicles are compound, long, and slender. The berries are small, from one-third to one-fourth of an inch in diameter; color black with a bloom, ripe in September and October.

The Frost Grape (*V. cordifolia*) has thin leaves, heart-shaped, sharp-pointed, sharply and coarsely toothed, and sometimes obscurely three-lobed. The bunch is compound, large, and loose. The berries are small, about one-fourth of an inch broad, and blue or black with a bloom, very acerb, and ripening after frost. Very late in autumn, when dead ripe, these grapes become comparatively sweet. As already intimated there are many forms that cannot well be classified with either of these species. Some appear to be hybrids, and some approach one or the other more closely, but varying much from them. In the opinion of some of our best botanists a thorough re-examination and a new classification of these wild grapes is needed. There is as much difference in flavor and quality as there is in form. Future investigation and culture will no doubt produce from these wild grapes varieties that will be eminently worthy of cultivation. Their superior hardiness, the ease with which they can be grown, their early bearing, and the comparatively fine flavor of many of them, entitle them to more attention than they have yet received.

A great deal of wine has been manufactured from these grapes in some portions of the State. The wine has a fine body, is rather dark, and in a year or two is much like the Oporto in flavor and color. It is sometimes shipped to other States to mix with wines manufactured from cultivated grapes to give them body and color.

The Mulberry.

Along the bluffs of the Missouri and some of its tributaries the Red Mulberry (*Morus rubra*) abounds. Sometimes it is a mere shrub, and sometimes it reaches the dimensions of a small tree. Though called the red mulberry, its fruit in Nebraska is as often of a blackish color, as red or brown. Its sweetish blackberry-like fruit is eagerly sought after by many of the settlers, and seems to be one of the special delights of prairie chickens, quail, wild turkeys, and other birds. At least I have often found them feasting on this fruit. This tree or shrub is easily cultivated, and is often transplanted for ornament and for its fruit into cultivated grounds.

The Buffalo Berry.

The Buffalo Berry (*Shepherdia argentea*) is found on the banks of the Missouri, the Niobrara, the Platte, the Republican rivers, and many of their tributaries. Though not yet seen in cultivation it deserves a place in every fruit garden. It varies from the habit

of a shrub to that of a small tree. The leaves are oblong, silvery white, the branches rusty white, and sometimes quite thorny, with numerous thorn-like limbs. The flowers are small, yellow, diœcious, the sterile ones with a four-parted calyx, and eight stamens. The fertile flowers have a calyx, shaped like an urn, which encloses the ovary that becomes the berry-like fruit. The fruit is roundish, varying in color from a dull red to a scarlet, slightly, but only slightly, acid, and until quite ripe, somewhat astringent, though agreeable. It is an enormous bearer, the fruit being produced in very compact masses in the axils of the branches. The fruit ripens in early autumn, and if left undisturbed hangs until winter. The plant is very hardy, and can be grown in any good soil. The only drawback to the cultivation of this fruit is that it is diœcious, and one of each sex must be planted to obtain fruit, though if many be planted in a row or cluster, one staminate or male tree will be enough to fertilize seven or eight pistillate plants. It is one of the easiest of all fruits to propagate. After the berries are gathered and the seeds removed from the pulp, they can be planted at once or kept in sand until spring. They ought to be sowed in drills and covered about two inches deep. At one year old they should be transplanted into ordinary nursery rows, about four feet apart. In three years from the seed they will bloom, when they can be examined, and labels attached to the staminate plants, after which, for convenience sake, each kind had better be placed in a row by itself.

Wherever this berry becomes known it is at once a favorite, and being so hardy and easily propagated it soon could supply the settler with an abundance of delicious berries. Among the purposes for which it is used is the manufacture of jelly, of which it produces an article that for richness of flavor is surpassed by no other fruit.

Sheperdia Canadensis, which is found on the Niobrara is scarcely less beautiful than the Buffalo Berry. Its fruit is less insipid than represented, and is even esteemed by many. The berry is yellowish red.

The Elderberry.

Many of the emigrants from the eastern States are glad to find an old favorite, the Elderberry, *Sambucus Canadensis*, among the wild fruits of Nebraska. Though the shrub which produces this berry has a rather rank smell, especially when bruised, and its fruit is seldom eaten in a raw state, yet the berries are really so delicious,

when prepared with skill, that wherever they abound they are eagerly gathered, and dried for future use, or manufactured at once into various kinds of jellies or sauce. A good article of wine is frequently made from them. The stems are half woody, from five to ten feet high; leaves pinnate; leaflets from seven to eleven, oblong, the lower often three parted; the flowers are small and white, in compound clusters or cymes; fruit, black purple. It grows abundantly all over eastern Nebraska.

The Papaw.

The Papaw, *Asimina triloba*, is one of the four North American representatives of a large tropical family, which is generally aromatic. Over three hundred species grow in the two tropical hemispheres. Its yellow fruit is from two to three inches long, is pulpy, with many flat seeds, fragrant, and ripe in October. The tree is from ten to twenty feet high. The leaves are thin, obovate, lanceolate, and pointed. The flowers are dull purple; the petals are veiny, round-ovate, and the outer ones from three to four times as long as the calyx. The flowers appear with the leaves and sometimes precede them. It is only found in the southeastern part of the State, and though of no practical value, botanically it is of much interest.

Nuts.

Though nuts are not always classed with fruits it seems proper in this place to mention the few that abound in Nebraska. First in the list is the nut of the noble Black Walnut (*Juglans nigra*). A few years ago this tree was abundant over eastern Nebraska. So valuable, however, is the wood, and so high the price it brings in market, that in many places where great numbers formerly existed it is becoming quite rare. Fortunately, this tree is so hardy and is so easily grown from the seed, that great numbers are started in the artificial groves that are planted all over the settled portions of the State. The nuts are almost as much of a favorite with adults as with children; and wherever the trees remain they should be carefully preserved to supply the means for future groves, and for the intrinsic value of their fruit.

In a few places along the Missouri the Shell-bark Hickory (*Carya alba*) abounds. Though not in sufficient quantities to supply the markets with hickory nuts, it is worthy of cultivation for its timber, which is valuable for many purposes besides fuel. When once

grown, groves of hickory will also supply an almost unfailing harvest of nuts.

The Hazel Nut (*Corylus Americanus*), is widely distributed over the State. It grows here from four to seven feet high. The nuts have been as much of a favorite with the Indians as they are now with the children of the white settlers.

CHAPTER X.

WILD GRASSES.*

The Most Valuable ones of Nebraska, with Notes on Their Perpetuation, and the Disappearance of the Buffalo Grass.—Origin of our Flora.

NEBRASKA is remarkable, among other things, for its wild grasses. They constitute everywhere the covering of the prairies. Even where old breaking is left untilled, the grasses vie with the weeds for possession, and often in a few years are victorious. Every close observer, passing through the State, in summer, must notice the great number of species, and their vigorous growth. I have in my collection 149 species of grasses that are native to the State. Of the sedges so closely related to them, there are also at least 150 species. Of course there is a great difference in the value of these grasses. Some of them are seldom or never touched by cattle, while others are sought out by them at all seasons. The following, so far as I have observed, are the most valuable:

Sorgum nutans,
Andropogon furcatus,
Andropogon scoparius,
Andropogon Virginicus,
Buchloe Dactyloides,
Sporobolus heterolepis,
Bouteloua hirsuta,
Bouteloua curtipendula,
Bouteloua oligostachya,
Festuca ovina,
Poa serotina,
Stipa viridula.

It is impossible to give a correct estimate of the proportions in which these grasses are found in Nebraska, as they vary a great

*First published in the New York *Tribune*, with the following note: "We take pleasure in introducing to the readers of the *Tribune* Prof. Samuel Aughey, of the University of Nebraska, an earnest. enthusiastic and thoughtful student, who is most esteemed where best known. In this, his initial article, he does not write from compilation or hearsay. He has been over nearly every square mile of the territory in question, some portions of it many times.—[*Ed. Tribune*."

deal from year to year in different parts of the State. In the eastern half *Andropogon furcatus*, *A. scoparius*, *Bouteloua curtipendula*, *B. hirsuta*, *Sorgum nutans* and *Sporobolus heterolepis* supply perhaps about two-thirds or three-fourths of the grazing and hay lands. For the purpose of ascertaining the value of these grasses, compared with cultivated ones, I have made an analysis of *Sorgum nutans* and *Andropogon furcatus*. The analysis of red clover, white clover and lucerne is that of Einhoff and Crome. For convenience, they are placed in parallel columns:

	Sorgum nutans.	Andropogon furcatus.	Red Clover.	White. Clover.	Lucerne.
Water	74.0	76.0	76.0	80.0	75.0
Starch	1.9	1.8	1.4	1.0	2.2
Woody fibre	14.0	14.0	13.9	11.5	14.3
Sugar	3.5	1.8	2.1	1.5	0.8
Albumen	2.1	1.6	2.0	1.5	1.9
Extractive matter and gum	2.9	3.7	3.5	3.4	4.4
Fatty matter	0.6	0.3	0.1	0.2	0.6
Phosphate of Lime	1.0	0.8	1.0	0.9	0.8
	100.0	100.0	100.0	100.0	100.0

The substances which produce fat, such as sugar, starch, and gum, contain the three elements of carbon, oxygen and hydrogen. Those that produce muscle, blood and nerves, like albumen, contain in addition to the preceding, nitrogen. Now, an examination of the above analysis shows that all the essential qualities for the best food for cattle are contained by these wild grasses. They are at least equal, if not superior in these particulars, to the best cultivated forage and hay crops. It will also be noticed that in phosphate of lime, so essential for the growth of bones ("and brain food?") these grasses are equally well supplied. The buffalo grass also contains three and six-tenths per cent of saccharine matter. I have not had time to carry out this analysis any further. First in the list of Nebraska grasses is *Sorgum nutans*, Gray. The only popular name that I have heard is one that I proposed myself, namely, sorgum grass. When growing in the early part of the season, it is not easy to distinguish it from blue joint. As soon, however, as its tawny, russet-like spikelets in a dense panicle, make their appearpearance, it is known at a glance among any number of other species. Toward the end of the season, the panicle nods. Spikelets are generally in pairs or threes, and are ciliate with a ring of

bristles at the base. The lower paleæ are tipped with a contorted awn. It grows from three to six feet high. I have seen it remarked that some seasons it does not produce seed. If that is the case in this State, I have failed to observe it. This grass has been increasing rapidly in Nebraska. It competes successfully with all its rivals for the possession of the soil. The amount now growing is treble what it was ten years ago. This season it monopolized the ground where, in former years, only stray stalks were seen. It produces the best hay if cut just before frost. For hay and for pastures it is one of the noblest of the grasses. I often noticed, when camped on the plains, that it was the first choice of horses after the buffalo grass that was within reach was all consumed. Whether it can be domesticated, remains to be seen. Three years ago an attempt was made to grow it on the Agricultural Farm, but the locusts ate it as fast as it came up. It did not survive the third time it was eaten off.

Andropogon furcatus, Muhl.—This is also a valuable grass in this State. It is sometimes called blue joint in the West. It is often confounded wite Andropogon scoparius, and even with Sorgum nutans. It is distinguished by having from three to five straight and rather rigid hairy spikes, from three to five inches long, together at the naked summit (Gray), and of a purple color. Occasionally there are lateral spikes. The stem is from four to six feet high. Some years it does not fruit, but the cause is not clear to me, as this occurs in wet and dry seasons.

Andropogon scoparius, Mich.—This grass is in some places even more abundant than the former, but generally it does not seem to be able to compete with it in the struggle for existence. I am not sure which of these two is the most valuable for feed. It is distinguished from the former by not being more than half as tall and by having a paniculate stem, one side of which is furrowed. The spikes are simple, lateral, and growing from the end on rather long peduncles, two or three being found on each sheath, and of a purple color. It is generally slightly silky and hairy. It is generally difficult to distinguish these two grasses until they begin to flower.

Andropogon Virginicus, L.—In a few localities in Southern Nebraska this grass is common. Though elsewhere it is of little repute; here I have often seen cattle grazing on it, and apparently enjoying it. No complaints have been made about it when used for hay. The stem is flat below, and somewhat downy with scattered

hairs. The leaves are long, narrow and carinate. Two or three spikes are together in different appressed clusters. It grows from three to four feet high.

Bouteloua oligostachya, Torr.—Until within a few years, this grass was only occasionally met with in eastern Nebraska, though common in the middle and western portions of the State, where it has often been classed with the gramma grasses. This common name, however, is indiscriminately applied to several other species in as many different genera. It is rapidly moving eastward. This year it was so abundant in Lancaster County that it in many places monopolized the soil, as could be seen on the wagon road between Lincoln and Milford. It is distinguished by spikelets of flowers hanging from one side of the axis or inflorescence. From three to five spikes are supported on each stalk. The color ranges from purple to indigo blue. Its height varies from ten to sixteen inches. It is exceptionally smooth and hairless, and is a perennial. For grazing, this grass is exceedingly valuable, and where it grows thick and strong, as it is beginning to do in many of the eastern counties, it makes most excellent hay.

Bouteloua curtipendula, Gray.—This grass is abundant in many places. It grows from one to three feet high, but the leaves are scanty, and it is not much sought after by stock. It is, however, a grass of great beauty. It can always be easily recognized by its racemes, which are from eight to fifteen inches long, and contain from fifteen to sixty small spikelets of a purple or scarlet color. For its beauty it deserves a place in the garden, if not in the field.

Bouteloua hirsuta, Lagasca.—This species is frequently confounded with B. oligostachya. The whole stalk is somewhat hairy. When ripening, the spikes are curved, short, and somewhat bristly, because of the great number of stiff hairs that grow from the dark colored glands of the glumes. In sterile situations in the western part of the State, it is short, but further east, where it is increasing rapidly, it is from ten to sixteen inches high. Though perhaps not so valuable as the preceding for forage and hay, yet here herds of cattle are often seen grazing on and apparently enjoying and fattening on it.

Sporobolus heterolepis, Gray.—This grass is abundant in some portions of the State. It makes good hay, for which it is often used. It grows from twenty-five to thirty inches high. Its leaves, which grow from the base of the plant, are thread-like and remarkable

for being as long as the stalk, and bending over gracefully until the tips touch the ground. It has a great tendency to produce stools. The stalk is naked above, bearing a small loose panicle whose sharp-pointed spikelets bear round seeds. The seeds, when bruised, give out a strong odor, which is offensive to some olfactories. It does not fruit in some dry seasons.

Spartina cynosuroides, Wild.—This grass is abundant in some places, but unfortunately, it is worthless. It is known as cord, and fresh water grass. It makes a poor article of hay, but its very abundance tempts many to use it for this purpose. Only extreme hunger will induce animals to eat it. It can be recognized by its slender stem, which grows from two to six feet high, and its narrow leaves, which are sometimes three and four feet long, and half slender points. The entire leaf, except the margins, is smooth. The straw-colored spikes are from two to three inches long, and from five to fourteen in number. They are scattered and spreading. A wide berth should be given to it.

Triticum —It sometimes happens that grasses which are comparatively worthless in one regard are valuable in another. This may come from the improved quality that soil, climate and situation give. Several species of *Triticum* which are everywhere regarded as almost worthless, in Central and Western Nebraska afford, in the early part of the season, good pasturage. It can be recognized by the character of the glumes, among which are the single spikelets at each joint, and placed with the side against the axis of inflorescence. Several species of *Festuca* abound in portions of the State, and make valuable forage.

Festuca ovina, L., is the most valuable. The culms and leaves are hard and wire-like, but exceedingly nutritious. The panicle is small and narrow, and the spikelets flat, numerous, and from two to six flowered. This grass has a tendency to grow in dense tufts, and is sometimes of a purple color. The stalks grow from ten to twenty-four inches high.

Bromus kalmii, Gray.—This grass is only abundant in the western part of the State, although it is occasionally met as far east as the Missouri. It is a perennial, producing a simple panicle, with spikelets drooping from simple capillary stems, and densely covered with silky hairs. These are sometimes flat and sometimes round, when matured. It grows from one to three feet high, and affords good forage. Some species of *Poa* abound in Nebraska. They

are very nutritious, and wherever found afford rich food for stock. *Poa serotina*, Ehrh, is perhaps the most important. It may be recognized by its open panicle, which branches in fives, the spikelets being pediciled, acute, a little flattened, and from two to four flowered. The flowers are acute, green, and occasionally tinged with purple. It grows from two to three feet high.

Poa Pratensis, L., is not native to the State, but has spread from old Fort Calhoun, north of Omaha, where it was probably introduced many years ago by the hay which the Government sent to the troops at this point. It has spread from this place over twenty-five miles of territory.

Buchloe dactyloides, Engl.—This is the famous buffalo grass which once grew over the whole region from the Missouri to the mountains. It is so well known that it scarcely needs any description. It rarely exceeds two or three inches in height, except the male flower stalk, which may reach five or six inches. The male flowers are in flat spikes on the top of the stock. The seed-producing flowers are almost covered by the leaves close to the earth. Both kinds of flowers are borne by the same plant, though the contrary was once believed. It forms dense tufts, spreading by stolens, forming broad mats. Engleman first detected the true botanical relations of this plant. This grass has always been a favorite with all kinds of stock. Often when camped on the plains, my lariated horses and mules would touch no other grasses until all the buffalo grass within their reach was consumed. This always occurred, no matter what other kinds of grass were present. This grass, before the advent of the white man, was the chief food of the buffaloes, which, in countless numbers, occupied the plains. It will be found that wherever the buffalo grass is not highly valued, it is confounded with *Munroa squarrosa*, Torr., which is an almost worthless species. It bears some resemblance to buffalo grass, and is often mistaken for it. But it is an annual with many branches from the base, creeping, and with the leaves clustered together. Of the disappearance of the buffalo grass, and my theory as to the cause, I will have something to say presently.

A word in conclusion as to *the way to perpetuate prairie pastures*. A complaint often heard in Nebraska is that in a short time the best of prairie grasses, such as sorgum nutans, Andropogon furcatus, etc., will, under severe pasturing and mowing, soon be exterminated, and their place be occupied by weeds. Where no chance is given

to the prairie grasses to recuperate, this is undoubtedly the case. It is found, however, that where fields of the best wild grasses are inclosed, and only mowed when mature, they will remain good meadows for many years. It soon kills these grasses to mow them early in the season, when or before they are in flower. I have frequently seen tracts of land inclosed where weeds had already gained partial possession, and by leaving them lie untouched for a number of years, the ground would again become thickly matted over with these rich grasses. With a little care, the new settler in Nebraska can get his supply of hay and pasture of the best quality from the prairies for a great number of years. He can be supplied, at least, until his own industry and advancement will prompt him to raise the cultivated grasses. Many of these wild grasses deserve to be experimented with. They have done so much to enrich the West already, that their cultivation, if possible, would be a great agricultural gain.

Disappearance of Buffalo Grass.

Buffalo grass (*Buchlœ dactyloides*) was once common all over Nebraska. Other species were present, but this grass was more abundant than all the others put together. It has now almost entirely disappeared from the eastern half of the State. Here it is now found only in isolated spots, which sometimes are slight depressions in the surface, some times elevations, and sometimes on a level with the plain. In examining the last retreats of this grass to ascertain the cause of its pertinacious life in such places, I invariably found that they were spots where the excess of alkali had entered into slight chemical union with the other ingredients of the soil, and more or less hardened it. This seems to indicate that such soils would be favorable to the cultivation of this grass; but whether this is the case, and whether, supposing this was possible, it is worthy of cultivation, remains to be determined by actual experiment. The manner and the cause of the disappearance of this grass is exceedingly curious. It cannot be caused by the ingress of domestic cattle. I have known whole counties from which the buffalo grass disappeared long before any domestic cattle or cultivation had interrupted the work of nature. For example, I visited Wayne County, Nebraska, for the first time in 1865, when as yet there was not a single white man or any domestic cattle within its bounds. And yet the buffalo grass was even then rapidly disappearing, and in a few years more was almost entirely gone. Many other instances of the same kind could be given.

Some old frontiersmen claim that the perpetuation of this grass depends on its seeds being scattered by the buffaloes, and that when they ceased to visit their old haunts it would necessarily have to die out. But it is difficult to understand why the foraging of domestic cattle would not have the same effect. It cannot be ascribed to the buffaloes' manner of cropping this grass. These animals sometimes pastured this grass more closely and constantly than domestic cattle. I have sometimes followed a herd of a few thousand buffalo and they seemed to eat the short, sparse grass in places almost out of the ground, leaving almost bare soil behind them. Causes with which neither the buffaloes nor domestic cattle have anything to do, evidently produce its extermination. The rate of its disappearance varies somewhat. In northern Nebraska it retreated westward at the rate of about twenty miles a year, until it reached its present eastern boundary. Along the Republican Valley, during some years, it has retreated at the rate of thirty miles a year, and other grasses, already mentioned in this chapter, took its place. In other years it has retreated more slowly. In favored localities it lingers behind several years longer, but even the alkali spots finally give it up. It is remarkable that the grasses that take its place are such as are indigenous to comparatively moist regions. I suggest, therefore, that change of climate, especially increase of rainfall, has most to do with this phenomenon. In Chapter IV was shown the constantly increasing rainfall in the State. It is the only fact competent to explain all the phenomena accompanying the disappearance of this grass on which the millions of buffalo, elk, deer and antelope had previously fed for ages.

Origin of Our Flora.

One of the questions that most frequently occurs to the thinking mind is when and how did our Flora originate? Did it originate here, or did it come by migration from some other region:

The earliest memorials of our present Flora are found engraven on the rocks of the lowest member of the cretaceous rocks of the west, known as the Dakota group*. In the chapter on the cretaceous deposits, the geological features of these rocks are given. Here are found impressions of the first oaks, cottonwoods, willows, maples, gums, hickories, walnuts, plums, cedars, pines, grapes, etc. The formation in which these early memorials are found, stretches

*See Lisquereux, Report on Cretaceous Flora.

through Kansas, Nebraska, Northwestern Iowa, Minnesota, Canada, and is found to appear in Greenland.

At the opening of the next, or Tertiary Age, in its lowest member, the Eocene, it makes its appearance in the far north in Greenland. Many of the species are identical with those now common in Nebraska. It is true that Heer pronounces these to be Miocene, but Dawson has shown them to be of Eocene age. (Report on Geological Survey of Canada.) By the time that the Miocene age commenced, they were still among the conspicuous forms in high northern latitudes. They emigrated southward with the gradually advancing cold of the Pliocene Age, and when the Glacial Age spread its mantle of ice over the north, they found a retreat in the southern United States and Mexico. At the final retreat of the glaciers, this Flora advanced northward, and found a home in central North America. The nearest allies, therefore, of our present Flora are the vegetable forms preserved in the rocks of the Tertiary Ages, in high northern latitudes. All life, vegetable and animal, probably commenced far north, and moved southward. The old idea, that it must have originated in tropical regions, has been eliminated from scientific belief by the advance of knowledge. This view also accords best with what is known of the history of the globe. The first known dry land was in high northern regions. Arctic lands first became cool enough to sustain vegetable and animal life. (Heer.)*

*See on this subject Gray's Forest Geography and Archaeology, Heer's Flora Fossilis Arctica; Dawson's Reports on Canadian Geology; Saparta, "Ancienne Vegetation Polairre"; Hooker's Presidential Address to the Royal Society.

CHAPTER XI.

FAUNA OF NEBRASKA.—VERTEBRATES.

Buffalo.—Deer Family.—Carniverous Animals.—Insect Eating Animals.—Birds.—The Leading Varieties.—Reptiles.—List of our Reptiles. Fish Culture.—List of Known Nebraska Fishes.

BEFORE the advent of the white man, Nebraska was a paradise for wild animals. Game of many kinds was amazingly abundant. Even the Indian could not keep it within due limits; it took immense numbers of the carniverous animals to do this.

Mammals.

Here was the empire of the buffalo, (*Bos Americanus.*)* The early settlers and the old freighters across the plains tell wonderful stories of the immense herds of buffalo which they so often encountered. Had I not myself, years ago, found large herds in places where there are now flourishing villages, these stories would appear like exaggerations. It is to be feared that the days of the buffalo are numbered. What the Indian alone could not accomplish, has been done by the remorseless war made on the buffalo by the white man. Now he is rarely found within the State. If he is perpetuated it will be done by domesticating him. Already some domesticated buffalo are found among the cattle herds in western Nebraska. Whether this experiment will be successful cannot yet be determined. No animal deserves to be perpetuated more than the buffalo. Buffalo robes are among the most important of commercial articles. Who has not been made comfortable by one? The buffalo is as readily tamed as the ox, and can be reared with as little difficulty. He is exceedingly hardy. He might be profitably reared for the pecuniary value of his hide. His flesh, which is considered coarse, would no doubt be refined by civilized environment. Even the buffalo's milk is a fair substitute for that of the domestic cow.†

*It will be understood that I only follow popular usage in calling this animal a buffalo. It is a bison. No true buffalo has a hump on his back.

†See an exhaustive treatise on the buffalo, in Hayden's Report for 1875.

Next to the buffalo, the elk (*Cervus Canadensis*) was the largest and finest native animal. It was formerly exceedingly abundant and is still often found in the northern and western portions of the State. Never shall I forget the magnificent herds of elk that crossed my path on the Niobrara and Elkhorn in 1866 and 1867. Their bulky bodies, huge antlers, and numbers, made them a picture never to be forgotten.

Four species of deer were formerly found here, and two of them very abundantly. These were the common deer (*Cervus Virginianus*), the white tailed deer (*C. leucrus*), the mule deer (*C. macrotis*), and the blacktailed deer (*C. columbianus*). The first and the last of this list were the most abundant, at least those are the species that I have most frequently seen myself roaming the prairies, and whose skins most frequently found their way to the traders. The special habitat of the black tailed deer was north Nebraska, and especially the Niobrara region.

Next to the buffalo in numbers comes the Pronghorn Antelope (*Antilocapra Americana*). It was formerly common to meet these on the prairie in herds of from twenty to five hundred. Only a few years ago it was yet common to meet herds of hundreds of these beautiful and graceful animals in central and western Nebraska. They are now mostly confined to the northern and western portions of the State. The antelope remains abundant after the buffalo and elk are gone, and when but few deer remain, and yet the last of them disappear before the deer is entirely exterminated from a district. The antelope is more disposed to go in herds than the deer; it frequently brings forth two at a birth, and while buffalo, elk and deer last they are often passed by, by frontiersmen. Their natural curiosity makes them an easy prey. It is well known that they will go close to a white covered wagon, or to a rag stuck on a ramrod in the ground, to ascertain what it is. The hunter, concealed in the grass, or behind or on one side of his wagon, easily secures one.

Bears have probably always been rare in the State. I have met but one in all my explorations in the unsettled portions. That one was on the Niobrara, and a black one (*Ursus Americanus*). I have also been reliably informed by old settlers that one was killed in the early history of Otoe County, on the Missouri bottom. I have been told by Indians that the cinnamon bear was formerly occasionally found on the Niobrara, but I regard this as doubtful.

Two raccoons are common in Nebraska, namely, the common raccoon (*Procyon loter*), and the black-footed raccoon (*P. Hernandezzii*). The former is the most abundant.

The Carnivora are well represented. The Panther (*Felis concolor*), is the largest, or at least the most powerful. I have only seen it a few times on the Niobrara and the Loup.

The Wildcat (*Lynx rufus*), is comparatively common in the wooded sections of the State. At rare intervals specimens of the Red Wildcat (*L. fasciatus*) are taken in north Nebraska. The common Canada Lynx (*Lynx Canadensis*), is widely distributed over the State, but few of them have been captured.

Several varieties of the timber wolf formerly were common in the State, but are now rarely heard of. The varieties were *Canus occidentalis*, *Var. nubilus* and the White Wolf (*C. occidentalis*, *Var. griseo-albus*). I have several times found this latter species lingering on the flanks of herds of buffalo, apparently on the lookout for any old animal that could not keep up with the herd, or was unable to defend itself.

The Coyote, or Prairie Wolf (*Canis latrans*,) was formerly exceedingly abundant. When on exploring expeditions in unsettled sections, the cooking of supper would invariably bring them around us through the night. They never venture to make an attack under such circumstances. I doubt whether a man is ever in danger from them. Settlers have destroyed so many by poison that they are now rare in the oldest portions of the State. A few, however, linger on even here.

Foxes have here disappeared more completely than the wolves. Formerly the Prairie Fox (*Vulpes macrourus*) was comparatively abundant, but is now rarely seen. The Swift (*V. velox*), however, yet holds his own in central and western Nebraska. The Gray Fox (*V. Virginianus*), was never abundant. The only specimens that I saw were in Pierce County, in 1869.

A few specimens of the American Sable (*Mustela Americana*) have been taken in northwestern Nebraska, but their presence within our borders is rare. The weasels, however, are abundant, there being at least seven species within the State. The most abundant are the Common Weasel (*Putorius noveboracensis*), the Long Tailed Weasel (*P. longicauda*) and the common Mink (*P. vison*). Those less frequently seen are the Least Weasel (*P. pusillus*), the Small Brown Weasel (*P. cigognanii*), the Little Black Mink (*P. nigrescens*), and the Black Footed Ferret (*P. nigripas.*)

The Wolverine (*Guleo luscus*) is yet found in central and western Nebraska, but it has never been abundant. The American Otter (*Lutra Canadensis*) is found more or less abundantly in all the rivers of Nebraska.

As would be expected, the Skunks are also here. Two species are common, namely, *Mephitis mephitica* and *M. occidentalis*. The American Badger (*Taxidea Americana*) was formerly common all over the State. The advance of settlements has almost exterminated it from the eastern part of the State.

Rodents are common here as elsewhere, but I am less confident as to the accuracy of my list. Many more must remain to be added to it when the State is once thoroughly examined with reference to this point.

Among the Rodents (gnawers), the squirrel family (*sciuridae*) are well represented by at least ten species. Among these are the Western Fox Squirrel (*Sciurus ludovicianus*,) the Gray and Black Squirrel (*S. Carolinensis*) and occasionally, in northern Nebraska, the Pine Squirrel (*S. Hudsonicus.*) Even the Flying Squirrel (*Pteromys volucella*) is sometimes found on the timbered bottoms of the Missouri. The Chipmuck (*Tamias striatus*) is rare, but the Missouri Striped Squirrel (*T. quadrivittatus*) is common over a large part of the State. Say's Squirrel (*Spermaphilus lateralis*) is abundant in some localities, and the Striped Prairie Squirrel (*S. tridecemlineatus*, is abundant all over the State. The Gray Gopher (*S. Franklini*), which is classed in this section, is common on theprairies.

Two species of Prairie Dogs formerly disputed between them the territory of western Nebraska. One of them (*Cynomys ludovicianus*) formerly lived in villages over the whole length of the State, from the Missouri to its western limits. It is now mostly confined to central and western Nebraska. Many thousands collect together in these villages. The other species (*C. Gunnisonii*). sometimes called Short Tailed Prairie Dog, is now only met in western Nebraska.

Two species of Woodchuck were formerly rather common in Nebraska. The common Woodchuck (*Arctomys monax*), is found at long intervals. The Yellow Footed Marmot (*A. flaviventer*). probably only found on the Niobrara. I never saw it alive, but met trappers who had skins of it obtained in that locality.

The Beaver (*Castor Canadensis*), was until recently common on all the streams of Nebraska. Even on the larger streams, like

the Platte, the Missouri and the Republican, where they could not build dams, they constructed excavated houses in the banks. Sections of trunks of cottonwood are yet found along these rivers, from eight to fourteen inches in diameter, which were gnawed off by beavers. They are now mostly confined to western and northern Nebraska, though a few linger on most of the streams of the State. The value and beauty of its fur causes a constant war to be waged against it by Indian and white man.

Of the Gophers, the Pouched Gopher (*Geomys bursarius*), is the most common, being found all over the State. The Short-headed Gopher (*G. breviceps*), is only rarely found in south Nebraska.

The Northern Pocket Gopher, (*Themomys talpoides*), whose habitat is placed far north by Coues and Allen, I found on the north side of the Niobrara in north Nebraska.

The Kangaroo Rat (*Dipodomys ordi*,) occurs in western and northern Nebraska on the Loup and Niobrara.

A rodent for which I know no popular name, but related to the above is rather common over western and central Nebraska. It is known among naturalists as *Perognathus fasciatus*. It is, without the tail, four inches long and mouse like.

The Yellow Pocket Mouse (*Cricetodipus flavus*), smaller than the house mouse is also common over central and western Nebraska.

The Wood Rat (*Neotoma Floridana*), is a native of Nebraska, but is only met with at long intervals.

The Bushy Tailed Wood Rat (*N. cinera*), only occurs on the Niobrara. At least that is the only section from which I have obtained or heard of it.

The White Footed Mouse (*Hesperomys leucopus*), is frequently found in almost every county in the State.

Another rodent (*H. sonariensis*), closely related to the above, is still more abundant. It has a shorter tail and lighter color than the preceding.

The Michigan Mouse (*H. Michiganensis*), found sparingly all over Nebraska. The Missouri Mole Mouse (*H. leucogaster*), is quoted as abundant in Nebraska by Coues and Allen, but I have found only one specimen here.

The Little Harvest Mouse (*Ochetodon humilis*), is common south of the Platte, but rare north of that river.

The Common American Meadow Mouse (*Avicola riparius*), is sparingly represented on the prairies of the State. The Prairie

Meadow Mouse (*A. austerus*), is rather abundant over the State, both on high bottoms and uplands. Still more abundant everywhere is the Western Prairie Meadow Mouse (*A. curtatus*). The Pine Mouse (*A. pinetarum*), occasionally occurs along the Missouri.

The Jumping Mouse (*Zapus Hudsonius*), is found only in the wooded portions of Nebraska. At least I have never met it anywhere on the prairies.

The Musk Rat is found in almost every stream of the State, and though much reduced in numbers by trapping still holds its own.

The Porcupine is present in the State in small numbers. It is the Yellow Haired Variety (*Erethizon epixanthus*).

The Hares are well represented in Nebraska. The Prairie Hare (*Lepus campestris*), is found in central and western Nebraska. The Varying Hare (*L. Americanus*), in some of its varieties, is common in the State. The Gray Rabbit (*L. sylvaticus*), is still more abundant than the former. The Jackass Hare (*L. callotis*), is abundant in western and central Nebraska, and more sparingly as far east as the Missouri. I have captured specimens within a mile of the Missouri bottom. Coues and Allen give its habitat here only as western Nebraska.*

The *Insectivara* are represented by only a few species. Five of these are shrews, belonging to one genus, namely, *Sorex pachvurus*, *S. richa*, *S. Cooperi*, *S. Haydeni* and *S. Hoyi.* I have not ascertained their relative abundance. Another genus of shrews (*Blarina*) is represented by three species, namely, *B. talpoides*, *B. brevicauda* and *B. exilipes*. *B. brevicauda* is the most common and abundant, being found almost everywhere in the State.

The Moles are more abundant in individuals. One of them (*Scallops Argentatus*) is abundant everywhere. Two others are rare, namely, *Condylura cristata* and *Uratrichus gibbsii.*

One *Marsupial* is rather common in the wooded portion of the State. It is the common Possum (*Didelphis Virginiana.*)

From the foregoing it is seen that at least eighty-two species of mammals are native to Nebraska.

Birds.

The bird Fauna of Nebraska is remarkably developed. It is particularly rich in genera, of which there are at least one hundred and fifty-six in the State. The species amount to at least two hun-

*For an exhaustive discussion of the Rodents, see "Coues' and Allen's Monographs of North American Rodentia."

dred and forty-nine.* At least, that is the number whose eating habits I have studied and described in a former publication. Since the publication of that work, nearly a dozen additional species have come to light within our territory. The fullest order is that of the Perchers (*Passeres*), of which there are eighty genera and one hundred and forty-seven species. Among these, the Singing Birds (*Oscines*) are represented by sixty-nine genera and one hundred and thirty-three species. The next division of this order, the Clamatores, are not so abundant, there being only eleven genera and fourteen species.

At the head of the Singing birds stands, of course, the glorious Robin, which is becoming more abundant each year. Four additional species of Thrush are here. The Mocking Bird is sparingly represented in south Nebraska, and the Cat Bird generally along the timber belts of water courses all over the State. In places the Sandy Mocking Bird is abundant. The common Blue Bird is in every community. The Western Blue Bird, formerly rare, is increasing in many places. Eight species of Wren, led off by the House Wren, abound. The Blue-eyed Warbler is common in all sections, but the Cærulean Warbler only along the wooded bottoms. This genus (*Dendraeca*) of warblers is represented by fourteen species, some of which are only here during their migrations. One of them (*D. discolor*) is very abundant, and breeds here. Of the Thrushes, the Golden-Crowned is the most abundant, and breeds within the State. One of the commonest birds is the Maryland Yellow Throat, and is on the increase in all parts of the State. Over the greater part of the State the Yellow Brested Chat is found. Six species of Swallow make their summer residence here. The most abundant is the Cliff Swallow. Its special home is in northeastern Nebraska. On one chalk cliff, east of the town of Niobrara, I counted twenty-one hundred nests which were made by this bird. There were other points near by where there were almost as many. The purple Martin is also common, and breeds here.

The vireos are represented by seven species, the most abundant of which is the Red-eyed Vireo, which can always be found in summer in the timber belts along the Missouri and other rivers. The Butcher Bird (*Collurio borealis*), which was formerly rare, is

*See the writer's faunal list and Natural Food of Birds, published in Report of U. S. Entomological Commissions for 1878.

now becoming abundant. Its old habit of impaling insects and small reptiles on thorns, is perpetuated here. The American Gold Finch, or Yellow Bird (*C. cristatus*), is a regular summer visitant. The buntings make things lively in winter. Five species come to Nebraska during this season. Among these, the Snow Bunting (*Plectrophanes nivalis*) is the most common. The Chestnut-collared Bunting is scarcely less common, and breeds here. Ten species, at least, of sparrows come to Nebraska, some of which are only present during their migrations. One of the most abundant is the Yellow-winged Sparrow. Great numbers of Lincoln's Sparrows pass through Nebraska on their migrations. The Long Sparrow is becoming more abundant each year, but the Tree Sparrow is only present in winter. The Chipping, Clay-colored and White-throated Sparrow are all rather common.

The Cardinal Grosbeak (*Cardinalis Virginianus*), is common in southern Nebraska. This beautiful bird so much admired as a caged pet, is rapidly on the increase. One owned by Mrs. Chapman in Plattsmouth, often wants to share half its worm or insect with its mistress.

The American Starlings are represented by many species. Among the most common are the Bobolink, Cow-Blackbird, Red-winged Blackbird, and Yellow-headed Blackbird. All these are very abundant.

One of the most abundant as well as most popular of Nebraska birds is the Meadow Lark. Its magnificent song in spring can be heard in all parts of the State and cheers every heart.

The orioles are becoming more abundant each year. The Baltimore and Orchard Oriole are especially becoming common. The Grackles are also here in large numbers, particularly Brewers and the Crow-Blackbird. The crow family is most largely represented, as elsewhere, by the Common Crow, though the Magpie is found in northern and western Nebraska. The Blue Jay is unfortunately found in places in large numbers. It is well known that it is destructive to the eggs and young of other birds, and should therefore be kept reduced in numbers by being made a target for sportsmen.

The Fly Catchers are well represented by eleven species. The King Bird is one of the most common. The Arkansas Fly Catcher is common only along wooded streams. The Least Fly Catcher is the most abundant, being found in almost every part of the State.

The *Piccarian Birds* are represented by eleven genera and fifteen species. Among these are the common Whippoorwill, in the eastern part of the State, and Nuttall's Whippoorwill in central and western Nebraska. The Night-Hawk (*Chordeiles Virginianus*) is common and breeds here. The Chimney Swallow is abundant in the older settlements of the State. The Humming Birds are represented by two species. The Belted King-Fisher is most frequently seen in the eastern part of the State. Seven woodpeckers are at home in the State. The Hairy, Yellow-bellied and Red-headed Woodpeckers are the most abundant. The latter is rapidly on the increase.

Birds of Prey are here in large numbers, though only a few that live exclusively on other birds. Among these is the Barn Owl which lives on insects. The Snowy Owl is here in winter. The Burrowing Owl so abundant in western and central Nebraska is a very large destroyer of insects, mice, and small reptiles. The Swallow-tailed Hawk, the most beautiful air sailer in America, feeds almost exclusively on insects. It is sparingly represented all over the State. The Pigeon Hawk and Coopers Hawk are unfortunately abundant all over the State. The American Merlin and Sparrow Hawk and Hen Hawk are common. Smainson's Buzzard is only abundant along timbered streams of water. The Golden and Bald Eagle are both occasionally seen in Nebraska, especially the latter, which has been known to breed here.

The *Pigeons* are very sparsely represented here, there being but two genera and two species. The wild Pigeons are abundant during some years. The common dove is very abundant all over the State.

Gallinaceous Birds are represented by only six genera and as many species. The Wild Turkey was formerly exceedingly abundant in all the woodlands of the State but is now much reduced in numbers. The Sharp-tailed Grouse has been reduced to a small number. The Prarie Chicken was once very abundant in Nebraska. Hunting them with dogs now keeps their numbers very much reduced. Quails are very abundant during some years. They are common over the greater part of the State.

The Wading Birds are represented here by twenty-six genera and thirty-seven species. Among these, the King Plover is abundant during its spring and fall migrations. The Piping and Mountain Plover are also common. Wilson's Phalerope is only common

in eastern Nebraska. Wilson's and the Gray Snipe are abundant during the migrating seasons. The Least and Baird's Sandpiper are also common during their migrations. The great Marbled Godwit breeds in the State. The greater and lesser Tattler abound here along rivers and creeks. The Wood Tattler occasionally breeds here. The most abundant of the tattlers is the Bartramian or Upland Plover. It is very abundant during its migrations and many remain to breed. The Long-billed Curlew was formerly very abundant and still is in the new sections of the State. Gunners easily frighten it away and the following season it rarely returns.

The Great Blue Heron comes occasionally to our rivers. The White Heron, Snowy Heron and American Bittern are rare in the State.

The Whooping and Sand Hill Crane are both in Nebraska, and the latter quite abundantly. The three species of rail in the State occur at long intervals. The American Coot, or Mud Hen, is often met in the State, and is remarkable for feeding on insects and mollusks.

The Anserine Birds, to which the swans, geese and ducks belong, are fully represented in the State. Ten genera and at least twelve species have been noted in my previous publications, and since then several more species have come to light. The Trumpeter Swan is here, but very rare. The White Brant is very abundant during its migrations. The common Wild Goose is equally common at these seasons.

The Mallard was formerly exceedingly common in the State during its migrations, but is now much less so, owing no doubt to the manner in which it is hunted down. Many formerly brought forth their young in northern Nebraska. The Green-winged Teal is also abundant during its migrations. The Blue-winged Teal and Shoveller are rarer than the preceding. The Wood Duck is common in some years, and breeds in north Nebraska. The Butter Ball and Ruddy Duck are common along the Missouri and on its tributaries for a short distance.

Of the *Totipalmate Birds*, only two species of Pelican visit the State.

Of the *Long-winged Swimmers*, there are four genera and ten species, one of which I found since my previous list was published. Of the Gulls, the Ring-billed and Franklin's Rosy Gull are the most common during the migrating season. Of the Terns, the

Least Tern and Black Tern are the most abundant. They breed in Nebraska.

The *Diving Birds* are represented in the State by only one species, namely, the American-eared Grebe. It is particularly abundant on the Platte and the Missouri.

This brief sketch will, I trust, give some idea of the affluence of bird life in Nebraska. I have in another work, already alluded to,* shown how highly insectiverous the most of our birds are, and what vast millions of insects they destroy. Bird life is the poetry of animal life. Every sentiment of admiration for exquisite beauty, for the charm of song, for utility, and abhorrence for the infliction of needless suffering, calls on cultivated and refined natures to protest against the needless destruction of birds.

Reptiles.

Owing to the large amount of time devoted to the other departments of our natural history, I have been unable to do much with our reptiles and fishes. The following is therefore only a partial list of such as I have found in the State:

Soft Shelled Turtle (*Trionyx ferox*). Missouri.

Snapping Turtle (*Chelonoura serpentina*). In most of our rivers.

Painted Tortoise (*Emys picta*). Missouri and Platte rivers.

Painted Tortoise (*Emys guttata*). Widely dispersed.

Wood Terrapin (*Emys insculpta*). Widely dispersed.

Geographic Tortoise (*Emys geographica*). Common.

Pseudo graphic Tortoise (*Emys pseudo graphica*). Rare.

Mud Tortoise (*Kinosternon Pennsylvanicum*). Rare.

Musk Tortoise (*Sternothacrus odoratus*). Have seen but one in the State.

Common Box Tortoise (*Cistuda Carolina*). Common.

Blanding's Box Tortoise (*Cistuda Blandingii*). Rare.

Saurians.

Blue Tailed Skink (*Suncus fasciatus*). Rare.

Fine-lined Lizard (*Lygosoma quinquelineatus*). Rare.

Horned Toad (*Phrynosoma carnuta*). West Nebraska.

Brown Swift (*Tropidolopis undulatus*). Niobrara region.

Chiroter lumbricoides. Southeast Nebraska.

Glass Snake (*Opiosaurus ventralis*). South Nebraska.

*Natural Food of Birds.

Snakes.

Black Snake (*Coluber constrictor.*) Common.

Pilot Blacksnake Racer (*Coluber Allegheniensis*). Rare.

Milk Snake. House Snake (*Coluber eximius*). Seen occasionally.

Ring Snake (*Coluber punctatus*). Seen at long intervals.

Grass Snake *Coluber vernalis*). Rare.

Coluber testaceus. West Nebraska.

Water Snake (*Trophidonotus sipedon*). Seen at long intervals.

Striped Snake. Garter Snake (*Trophidonotus taenia*). Rare.

Yellow Bellied Snake (*Trophidonotus leberis*). South Nebraska.

Small Brown Snake (*Trophidonotus DeKayi*). Some seasons rather abundant.

Little Garter Snake. Ribbon Snake (*Leptophis saurita*). Rare. Only in timber.

Bull Snake (*Pituophis melanoleucas*). Common.

Northern Rattlesnake. Yellow Rattlesnake (*Crotalus durissus*). Sparingly. Most abundant in North Nebraska.

Michigan Rattlesnake (*Crotalophorus miliarius*). Rare.

Western Rattlesnake (*Crotalophorus tergeminus*). Rare.

Massasaugua. Prairie Rattlesnake (*Crotalophorus Kirtlandi*). Now supposed to be the same as the preceding. Formerly abundant.*

Harlequin Snake (*Elaps fulvius*). Rare.

Amphibians.

Bullfrog (*Rana pipiens*). Common.

Northern Bullfrog (*Rana hariconensis*). Rare.

Spring Frog (*Rana fontinalis*). Rather numerous in favorite localities.

Marsh Frog. Leopard Frog (*Rana palustris*). Common and abundant.

Shad Frog. Lopard Frog (*Rana halecina*). Common.

Wood Frog (*Rana sylvatica*). Common in timber along the Missouri.

Common Toad (*Bufo Americanus*). Common.

Missouri Toad (*Bufo cognathus*). Occasional.

Northern Tree Toad (*Hyla versicolor*). Along the Missouri.

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*For the use of the rattles of the Rattlesnake, see the writer's paper, published in the "American Natnralist," Feb., 1872.

Tailed Batrachians.

Yellow-bellied Salamander (*Salamandra symmetrica*). Occasional.

Violet-colored Salamander (*Salamandra subviolacea*). Rather common.

Blotched Salamander (*Salamandra fasciata*). Common.

Long-tailed Salamander (*Salamandra longicauda*). On the Niobrara.

Striped-back Salamander (*Salamandra bilineata*). Rare.

Red Salamander (*Salamandra rubra*). South Nebraska. Rare.

Blue-spotted Salamander (*Salamandra glutinosa*). Rare.

Banded Proteus (*Menobranchus latteralis*). Rare.

Allegheny Hell-bender (*Manapoma Alleghenienis*). Occasional.

Fishes.

The following list of our fishes includes only the few that I have identified. For reasons already stated, I could not devote myself to a special investigation of our fish fauna. One-half of our species are not included in this list.

The waters of Nebraska are eminently adapted to the artificial propagation of fish. Even the trout can be successfully reared in many of our streams, especially in some like the Bows, in north Nebraska. These Bow Rivers are largely made up of the most delicious springs along the greater length of their course, and where these are most abundant never freeze over in winter. The Bazile is equally well adapted to this industry. There are also many kinds that will flourish in the Elkhorn and its tributaries, the Nemahas and their tributaries, and the Blues and Loups and their tributaries. There are other rivers and their tributaries that could be stocked equally well with choice fish.

Bony Fishes.

Many-lined Bass (*Labrax multilineatus*). Missouri River.

Pike Perch (*Leuciaperea grisca*). Occasionally found in the Missouri.

The Growler (*Grystes salmoides*). Rare. Missouri and Nemaha.

Black Bass (*Centrarchus fasciatus*). Elkhorn, Logan, etc.

Centrarchus pentacanthus. Nemaha. Rare.

Pond Fish (*Pomotis vulgaris*). Common in most of our streams.

Three additional species of Pond Fish (*Pomotis*) not identified.

Lake Catfish (*Pimeloidus nigricans*). Missouri, Platte.

Common Catfish (*Pimeloidus catus*). Common.

Forked Tail Catfish (*Pimeloidus furcatus*). Missouri.

Brazen Catfish *Pimeloidus deneus*). Platte and Elkhorn.

Blue Catfish (*Pimeloidus celurescens.*) Missouri, Republican, Nemaha, Elkhorn.

Yellow Catfish (*Pimeloidus cupreus*). Probably same as Brazen Catfish above.

Channel Catfish (*Pimeloidus pallidus*). Missouri, Platte, Blue, Elkhorn, etc.

Mud Catfish (*Pimeloidus nebulosus*). Common.

Black Bullhead (*Pimeloidus xanthocephalus*). Missouri and Niobrara.

Four additional species of catfish I failed to identify.

Chubsucker (*Labeo* ———). Only occasionally seen.

Sucker (*Catastomus* ———). Missouri.

Black Buffalo Fish (*Catastomus elongata*). Common.

Shiner (*Stilbe chrysoleucas*). Platte, Missouri.

Black-nosed Dace (*Lenciscus abronascus*). Same as above.

Vermillion-eyed Dace (*Lenciscus biguttatus*). Platte, Bow, Blue, Elkhorn, etc.

Chubb Big Head (*Lenciscus cephalus*). Bow Rivers.

Minnow (*Hydrargira* ———). Common.

Muskallonge (*Esox ester*). Missouri. Rare.

Common Pickerel (*Esox reticulatus*). In most of our streams.

Missouri Trout (*Salmo Lewisi*). I caught one in the Bow and one in the Iowa Creek, in Dixon County. Probably wandered down from the upper Missouri.

Gar Pike (*Lepidosteus* ———). Common.

Western Mud Fish (*Amia occidentalis*). Rare.

Common Eel (*Anguilia tenuirostris*). Elkhorn River. Rare.

Cartilaginous Fishes.

Sturgeon (*Aeiphensex maculosus*). Missouri. Rare.

Lamprey (*Pteromyzon* ———). Elkhorn. Rare.

CHAPTER XII.

INSECT LIFE.

Number of Species.—Predatory species.—Chinch Bug.—Army Worm.—Hessian Fly.—Potato Beetle.—Insects that prey on orchards and groves.

IN articulate animal life, the most important class is that of insects. As in temperate latitudes generally, they are more numerously developed in genera, species and individuals than any other section of the animal kingdom. In fact, they dispute with man the empire of the world. During spring and summer they are omnipresent ; when the naked eye does not recognize them the microscope brings them to light. In Nebraska the number of species is very great, approximating to eight or nine thousand. About one-fourth of these are predatory and non-injurious species, leaving not less than six thousand, or two and a half injurious species to every species of plant in the State. This calculation is based on the original constitution of the State, and not on the condition into which it has been brought by civilization. The great body of injurious species are so few in number that they rarely do any damage that is noticeable. Here, as elsewhere, only exceptional conditions, as a rule, develope injurious species to a temporary and damaging multitude. Judging from observation for fifteen years, the insects which we have most to dread are the chinch bug, army worm, Hessian fly, potato beetle, the insects which prey on our orchards and groves, and the locusts.

The Chinch Bug

is the dread of the agriculturists of the Mississippi Valley. It sometimes occurs in Kansas in enormous numbers, and the probabilities are that it is more to be dreaded on the plains of Nebraska than even the locust. I fear it is on the increase. At least, during the last season more have been sent to me for examination than ever before. And although most persons are familiar with its general life-history, I will repeat it, because I believe that here it has slightly changed its habits; at least, some individuals

have done so. The reports say that about June the eggs are laid on the ground or among the roots of plants, and that this process of egg-laying lasts fifteen or twenty days, and that they number about 500 for each female. In fifteen days the eggs hatch out. The bright red larvæ remain under ground, sucking at the roots of plants. The full grown insect is one-twelfth of an inch long, of a black color, with white wings, and appears from the middle of July to August. A second brood hatches out still later in the summer, and further south a third brood. Evidently some of the perfect insects survive the winter, harboring under rails, boards, leaves and grass. I found them frozen solid, apparently, during the last winter, when hunting for locust eggs, but they soon revived when brought into a warm room. Now here I have found the chinch bug vary from this history in this, that it occasionally deposits its eggs on the lower part of the plant itself, as I ascertained by bringing such plants home an l observing their transformations. As the damage done by this insect sometimes in western States like Illinois reaches as high as $73,000,000 in a season, it is important to note the remedies that have been devised against them. Lady bugs (*Coccinellidae*) destroy them, as also lace-wing flies. During the last summer I dissected several quail, whose stomachs were filled with these bugs. The protection of quail, therefore, must have a salutary influence on restraining their increase. The methods devised against the chinch bugs are various. Among the best are ditching to keep them from traveling from one field to another, and keeping the ground constantly stirred. They appear to dislike ground that is yielding, or that dirties their bodies. By ditching, as many as forty bushels have been destroyed in one day. One plan is to drag a log through the ditch to kill them, and another is to dig pits in the ditches in which they are buried or otherwise destroyed.

The Army Worm

(*Leuicania unipucto*,) as far as I know, has not yet done any injury to the crops of the State. I was at least three years in the State before I found a single moth of this insect. The first one I found was in the autumn of 1867. No more came across my path till 1869. The first autumn (that of 1871) that I spent at the University, I found great numbers, and on the whole they have been increasing ever since. Here probably two broods are raised in a year. The eggs are laid near the roots of the prairie grass in June or July, and lie dormant till the next spring.

Remedies.—Hence a successful method of warring against them has been the burning of plots of grass where they abound. Mr. Walsh, the former eminent entomologist of Illinois, after a long study of this insect, became confident that this is an infallible remedy. And of course, where the larvæ or worm makes its appearance, ditching must be resorted to as in other cases with marching destructive insects. And I have no doubt that our immunity thus far from occasional depredations from this enemy has been the yearly burning of large tracts of the prairies of this State. And just in proportion as this practice is abandoned for other reasons will the dangers from this source multiply. I have received a few letters from different portions of the State complaining about the appearance of

THE HESSIAN FLY.

This is no indication that it will become troublesome, and yet, to be forewarned is often to be forearmed. I have had no experience to amount to anything with this insect.

Habits.—But it is said to deposit its eggs in the long slits of wheat, grass, barley and rye blades, etc., both in spring and fall. In from five to twenty days the eggs hatch. The larvæ crawl down between the leaf and the stock until they reach a joint, where they rest and suck the sap. They mature in from four to five weeks. The pupa has a striking resemblance to a flax seed, and is found at the same place where the larvae was sucking the sap. In April, May or the first of June, the winged insect appears, and commences egg-laying.

Remedies.—It is also said that large numbers of the pupæ are destroyed by cleaning off all the stubble by deep plowing, but especially by burning over the fields. Quicklime scattered over the fields after harvest has also been relied on in some places in the east as a remedial agent. Strewing the fields in April and May with wood ashes has also been found efficacious.

The larvæ of the wheat midge (*Diplasis destructor*) has also been sent to me this season, but to what extent it prevails in the State I am unable to say.

FRUIT DESTROYERS.

I have observed no indications of any special increase in the species that prey on orchards and groves, except in the case of plant-lice, which have been abundant for several years past. It is well known that the species are exceedingly abundant,

and that they increase with marvelous rapidity, a single pair being capable by the end of the season of producing millions. The conditions of their great increase during some seasons and their decrease during others are not well understood. During this season they were abundant not only on the milkweeds, amorphas, and some few sun flowers, but were specially abundant on oak trees, on the willows, elms and cottonwoods, though I am not advised as to any particular damage that they have done. It is claimed by many that a moderate increase of plant-lice is an advantage where apiaries are kept, because of the heavy honey dew that some species produce. This is questionable, but it is one of those compensations of which nature is so full. Something at least is gained, if when the vigor of vegetation is impaired by the sucking of wood-lice, the bees produce double their ordinary stores. For a few years, in many portions of the State, there has been an alarming increase of the

COTTONWOOD LEAF BEETLE,

or, as it is known to science, the *Plagiodera scripta*. Nowhere has it done more injury than in Lancaster County, though it has been sent to me to identify from many other places. Some of the groves beyond the Antelope, and many of the cottonwoods on the State Agricultural Farm, were despoiled of their leaves by this insect. It prevailed as far north as Dakota and Dixon counties. I saw trees stripped of their foliage by it in Burt and Washington counties. It has done more or less damage in at least twenty counties of the State. During this season, however, it has greatly declined in numbers, and in the damage it has been doing for several past years. What has caused all this decrease I am unable to say, but one element of the process has been the work of predatory insects. I have found ichneumons and chalcis flies at work on them. Rainy seasons also seem to be injurious to them. This, however, has been denied. The fears, however, that many began to entertain that this insect was going to place an embargo on the cultivation of the cottonwood, is proved to be not well founded. Prof. Culbertson I think has somewhere given an account of its life history, and the best methods of counteracting its work, and that, therefore, I need not here repeat.

During this season, also, the various species of borers have not, so far as I am advised, made any special inroads on the trees of the State. I have no doubt the increase of our insectiverous birds has had much to do with lessening the number of many of our insect enemies.

Since the first settlement of the State,

THE MATERIAL CONDITIONS IN RELATION TO INSECTS

have greatly changed, and are still in process of change, and more rapidly than ever. Forests have been removed in some places, and planted in hundreds of others. Whole counties have been rapidly transformed from raw prairies to cultivated fields. The old balance between insects and plants has been disturbed. The natural food of the insects has been removed, but the insects themselves probably remained. No alternative then remains but for the insects, in accordance with natural law, to adapt themselves to the changed condition. If man takes away their natural food, they will naturally confiscate, or try to, some of his. For the loss of the spontaneous vegetable productions of the State, they find compensation in corn fields, vineyards, orchards, gardens, wheat fields and clover and timothy and clover fields. If the new vegetable forms introduced into the State had only native foes to fight, the struggle for existence would not be so severe. But in addition, other foes, old enemies from their native climes, follow them. The apple tree and the vine, the peach and the pear, in their westward march, have gathered the foes of all climes and all lands, until their numbers are legion.

Friends and Enemies.—Still with the enemies that have accumulated, came some friends, often in disguise. Vast numbers of insect parasites often make their appearance to re-establish again the broken harmony of nature. Thus ever changing man keeps nature in turmoil in her efforts to adapt herself to the newly imposed conditions. Insect enemies sometimes make their appearance and increase with such amazing rapidity as to threaten the entire destruction of some horticultural or agricultural industry. Finally an enemy stealthily makes its appearance, sometimes from the native region of the plant, and sometimes from other lands. The abundance of food favors its rapid increase, until in a few years it has almost wholly destroyed the source of its food, when both fall back to the narrow dimensions, and the obscurity from which they had emerged. This continued disturbance and readjustment of the relations between insect life, horticulture and agriculture must, in the nature of things, continue for a generation. This involves the continued need of watchfulness and special labor in the entomological field. We need for our State

A MANUAL OF ECONOMIC ENTOMOLOGY,

—such a one as Harris prepared for Massachusetts—that is, one similar in plan, but very different in specific detail. For one-half of the insects that are troublesome in Massachusetts do not give us any concern here, while the great body of our injuricus species were unknown in Harris' day. But while there is a great need for such a work, it cannot yet be prepared, because many of our injurious species are as yet neither known nor studied. But every friend of horticulture can aid in the preparation of such a work, by keeping a careful record and close notes of the habits and life-history of such species as come within his observations.

CHAPTER XIII.

THE LOCUSTS*—MOLLUSKS.

Nativity.—Spring History and Migration.—Numbers that Light Down.—Egg Laying.—Manner of Egg Laying.—Hatching.—Departure of Locusts.—Destructiveness of Locusts.—How to Combat and Destroy the Locusts.—Nature's Methods of Destroying Locusts.—Invertebrate Enemies.—Vertebrate Enemies.—Extent of Locust Invasions.—Probable Future of Locust Depredations —Mollusks.

NOTHING in the natural history of Nebraska has excited such general interest as the locust question. Where then, do they breed, how frequently do their visitations occur, and what is the amount of damage which they do?

The migrating locust, (*Caloptenus spretus*,) is native to the high and dry regions of the Rocky Mountains. Its permanent habitat is the region between latitude 43° and 53° north, and 103° and 114° west of Greenwich. Even some portions of this section are sometimes deserted for a few years for other grounds, but always somewhere within this territory they will be found to exist. In a majority of years some locusts will also be found to breed south of the above line, along the region west of longitude 105° 30′. The

*The reader is referred for a detailed account of the Locust question to the Report of the U. S. Entemological Commission for 1877, which includes the writer's investigations and conclusions on this subject at greater length and fulness.

great interior region between the Wasatch and the Sierras over much of its territory will be found to harbor a few during most years. Whenever, therefore, over these regions the conditions are favorable they increase to astonishing numbers. These favoring conditions are exceptional dryness and warmth. If two such seasons follow each other in the native habitat of the locust they are sure to migrate.

Their Spring History and Migration.—After they hatch out in the spring it takes about seven weeks before they reach their full growth. During this time they moult five different times, and each time change slightly in color. Only at the last moult are full wings acquired, the thorax flattened and the insect ceases to grow. Where now they cover the ground in their native haunts from their abundance the scanty vegetation is soon exhausted. It is now that they manifest their peculiar instincts. They take short flights for several weeks, apparently to test and strengthen their newly acquired wings. The warm pleasant days with gentle winds are the favorable periods for flight. When all is in readiness they rise from eight to ten o'clock in the forenoon and move off with a rapidity dependent on the wind, varying from three to fifteen miles an hour. They do not move in broad sheets, but in columns like fleecy clouds from one to five thousand feet thick. They sometimes continue their flight through clear, warm, moonlight nights, but more generally come down between three and five o'clock to feed. On the following day they continue their flight if the weather is favorable. A change of wind or fall of temperature brings them to the ground at any time. From their native habitat they move mainly in an easterly, southeasterly, and southern direction. Moving in this direction those that commence migrating from Montana by the middle of July reach Nebraska and Kansas some time in August or September. They do not always deposit their eggs where they first light down. Frequently they remain from one day to three weeks and then move farther on before egg laying is commenced.

The Numbers that Light Down is often enormous. In 1866 in Cedar County, during July, they appeared in such numbers that the sun was darkened. The limbs of trees bent down and broke under their weight. It was exceedingly difficult for one to move through the living mass. Others have had, and reported similar experiences. It is true that such cases are extreme and exceptional,

and occur at long intervals over limited areas. It has been no uncommon thing, however, for them to be so abundant as to entirely cover the ground.

Egg Laying.—The time for the commencement of egg laying varies somewhat in different years and localities. Generally it commences about the middle of August and continues to severe frost, and lasts therefore from six to eight weeks. In 1876 the locusts were laying eggs far into October. The female generally lays three times, at intervals of from three days to three weeks. Each egg mass contains from twenty to thirty-five eggs.

Place and Method of Egg Laying —The places for egg laying are not uniformly the same. They seem to prefer ground that is high and dry, and somewhat compact. Low lands, however, that are dry are much used for this purpose. Road sides are frequently honeycombed with holes, but comparatively few egg masses are found there. New breaking is generally fuller of eggs than any other kind of ground. The number laid is often simply enormous. I have often found sections of land where the eggs averaged from ten to fourteen thousand, and in rare instances to upwards of twenty-one thousand to the square foot. These enormous numbers are only reached during years when the locust swarms are exceptionally dense.

Manner of Egg Laying.—When the female is about to lay her eggs she selects a spot and " forces a hole in the ground by means of the two pairs of horny valves, which open and shut, at the tip of her abdomen, and which from their peculiar structure are admirably fitted for the purpose. With the valves closed she pushes the tips into the ground, and by a series of muscular efforts, and the continued opening and shutting of the valves, she drills a hole until in a few moments (the time varying with the nature of the soil) the whole abdomen is buried. The abdomen stretches to its utmost for this purpose, especially at the middle, and the hole is generally a little curved and more or less oblique. Now with hind legs hoisted straight above the back and the shanks hugging more or less closely the thighs she commences ovipositing." (Riley.) Before the eggs come out there exudes from the end of the body a mucous matter which fills the bottom of the hole and bathes the valves. The eggs separately, by convulsive throbs, are placed in order in the hole. The mucous matter binds all the eggs together. When the locust is through with this process, she fills the upper

end of the mass with the same mucous matter, and then shuts up the hole carefully. This mucous after hardening is only pervious to water under frequent changes of temperature and during long wet seasons.

When severe frost comes the old die off rapidly and at the appearance of permanent cold weather they have all disappeared.

Hatching.—It often happens that during the long dry autumns of Nebraska, great numbers of the earlier laid eggs hatch out and soon perish with the cold of winter. Many eggs also become segmented in autumn and whether they survive till spring in a healthy condition is still with many a disputed question. My own opinion, derived from the closest observation, is that all such come out in the spring, if they come out at all, in a sickly condition and soon perish. Sometimes, too, as happened in 1877, there is much warm weather in January and February, during which great numbers hatch out that invariably perish by the subsequent cold weather. During spring the great hatching months are March and April. In these months cold always interrupts the process. This occurred in the Spring of 1877, when there were many cold days and chilly winds, and as a consequence hatching was not over till early June.

Departure of Locusts.—As already stated, a few days after the last moult on favorable days they are disposed to migrate. No exception to this rule is known in the region of the plains. It is possible that where they are few in number in their native habitat they do not always migrate, but even that is uncertain. In Nebraska, Iowa, Dakota, Kansas and Missouri they are disposed to return to their native regions. They therefore move mainly northward and westward. Their instincts seem to force them to dryer and higher regions, where they originated. Such was specially the case when countless millions left the State in 1876. During 1877, the spring of which was rainy, cold and chilly, the greater part of those that hatched out soon perished, and the few that survived seemed sickly and demoralized. These survivors first mainly moved northward, and then moved southward, and finally were seen to move in all directions; often two columns, one above the other, moving in opposite directions. The greater part of this season's product of locusts evidently ran out, and perished by too long a stay in a region unadapted to them.

Destructiveness of Locusts.—When the migrating locusts make their appearance in Nebraska, the cereal grains are already har-

vested. Wheat, oats and barley are safe. Corn and the gardens are the victims, if they come before the former are sufficiently ripened to resist their attacks, which is not always the case. A swarm of locusts in July or August can ruin a field of corn in a few days, and sometimes in a few hours. Often the fields are only partially destroyed. Sometimes the silk and foliage is partially eaten off, and the ends of the ears bared, so that the crops cannot mature. If they leave at this stage of their proceedings, all is well, and if not, their eggs are deposited and the wheat crop endangered during the coming spring. The countless numbers that are hatched out, if the spring is favorable to them, become exceedingly voracious. As they soon commence to move by jumping in one direction, when abundant, they are apt to devour everything in their path. This continues until they are old enough to fly, when they depart for other regions. Generally some corn can be saved in spring, and late planting may entirely escape. Often the third planting of corn during locust years yielded a fair crop. The cereal grains, however, have in some places, and during some years, been largely destroyed during the time between the hatching out and flight of the locusts.

How to Combat and Destroy the Locusts.—No successful method has yet been devised to destroy the locusts on their first appearance in migrating swarms from the northwest. The injury, as already stated, which they now do is to the corn crops and the gardens, and sometimes to young growing fruit and forest trees. The eggs, however, which are laid in autumn, have been frequently destroyed by repeatedly harrowing the ground, breaking up the nests, and exposing them to the action of rain and cold and birds. Hon. R. W. Furnas, of Brownville, who first to my knowledge devised this method, found it to be very successful. Plowing them under very deep, also destroys great numbers. When they hatch out in spring in destructive numbers, the most vigorous methods need to be employed. One of the most successful ways of destroying them is the digging of ditches around fields across the path on which they are moving. If the trenches are made from twelve to fourteen inches deep, and still deeper holes dug every few rods in the trenches, the young locusts first get into the trenches, then into the holes, where, unable to get out, they can be destroyed by piling ground on them. I have known many farmers to save their entire crops in this way in the very midst of the most infected districts.

Still others have saved their crops by a system very generally in use in the spring of 1877. Pans made of sheet iron, from five to ten feet long, low in front and high behind and at the sides, with cross partitions from front to rear, is the general plan of the apparatus used. A little coal oil is placed in these pans, and dragged over the fields by hand or horse power. The young locusts jump into or over the pans, and even the fumes are fatal to them. In this way I have known fourteen bushels to be captured in one day by one man. The combination of these two plans—ditching and coal oil pans—will save any farm in the spring from the ravages of the brood hatched in that locality, if commenced in time. Unfortunately, farmers too often simply look on until their crops are partly destroyed, before anything is done to protect themselves. It requires energy and decision to do this, but when it is properly commenced and persevered in, it is successful.

Nature's Method of Destroying Locusts.—Nature has placed limits to the increase of the individuals of a species. When there is an undue increase from exceptional favoring conditions, either natural enemies soon proportionally increase or the need of food compels migration, which often forces to unhealthy regions. This is the case with the migrating locust. Its native habitat is a high, dry region, where the rainfall is from ten to twenty inches a year. It cannot long endure a combination of low altitudes and moisture, combined with extreme and sudden changes of temperature. Hence, the locust can never become localized in Nebraska. The memorable spring of 1877 is a notable illustration of this fact. In March and April immense numbers hatched out, and then followed cold rains, with sudden alternations of extremes of temperature. Countless millions of young locusts died. Many spots where the ground seemed to be covered with them, none could be found in a few days. Nothing often convinced me that death was the cause of their disappearance, until, getting down on my hands and knees and examining the ground with a huge magnifying glass, I found their dead carcasses. The young brood just hatched out disappeared as if by magic from whole counties. The localities where much damage was done were exceedingly few. In fact, the brood was so impaired constitutionally that it fell an easy victim to the extremes of a moist climate in a comparatively low altitude. I also noticed, in previous locust years, that moisture accompanied by an extremely hot or cold day was always fatal to many of them.

Invertebrate Enemies.—It is a law of nature that the undue development of any animal is checked sooner or later by a like increase of its natural enemies. Were it not for that law, the slowest breeding species would soon overrun, to the exclusion of all other animals, its own special habitat.

Among locust egg destroyers, no insect equals in efficacy the Anthomyia egg-parasite (*Anthomyia angustifrous*). A few were noticed in 1874, and by 1876 it destroyed about ten per cent of the eggs in Nebraska, and Prof. Thomas reports an equal destruction in Kansas, Missouri, Iowa and Minnesota. He also remarks that "we never dug for five minutes among the locust eggs, anywhere in our travels during May, without finding this parasite, in various stages of development." It is a small white magot, and is found in the locust egg pod extracting the juices and leaving nothing but dry dissolved shells. From this magot is developed a small gray two-winged fly, about one-fourth of an inch long. The common flesh fly, many species of Ground, Blister, Soldier and Dick beetles, also prey on locust eggs.

After the locusts emerge from the eggs, their greatest insect enemy is the Locust Mite (*Trombidium locustarium*). It also preys on the eggs. The parent mite lays from three to four hundred eggs, and therefore increases at a prodigious rate. The young mite manages to fasten itself on the locust, especially during and after rains, and mostly lodges under the base of the wings. Such numbers are often found lodged on single locusts as necessarily to produce death. During locust flights, I have frequently seen hundreds fall to the ground, which, on examination, proved to be partially destroyed by these mites. Ground beetles, Asilus flies, Flesh flies, Digger Wasps and Tachina flies, especially the latter, also feed on locusts and destroy great numbers. Hair worms, Spiders, Soldier-bugs and Dragon flies also prey on the locust.

Vertebrate Enemies.—Among vertebrates, no animals equal the birds as destroyers of insects, and especially of locusts. The numbers of locusts which birds consume is simply incalculable. Many species in locust years live entirely on them, and most do so partially. Often each bird of a species captures several hundred during each day. In fact, after many years' study of this subject, and after dissecting more or less of several hundred species, I have been forced to the conviction that even the gramnivorous birds cannot be excluded from the list of locust enemies. The reader will find

the record of each case of dissection of over 200 species of our birds, which I made during many years, in the report of the U. S. Entomological Commission for 1877. It is clear to my mind that few as yet appreciate the great and commanding importance of protecting our birds. If this was properly done, few species of insects would ever increase to destructive numbers. Unfortunately, the savage is still dominant in man, and many calling themselves cultivated regard it sport to maim and kill innocent birds. Such a course destroys the harmony of nature, and one of the consequences is the devastations of insects.

Extent of Locust Invasions.—Unfortunately, the human mind has a tendency to exaggeration. Owing to this, during every locust invasion, the damage done has been over-estimated. In 1874, 1876 and 1877, they did much damage, but by no means as much as was reported. The drouth, and human indolence and carelessness, did much more. I knew men during these years that never touched their corn after it was planted, and of course, got none, as they did not deserve any, who yet charged the locusts with destroying their crops, though none had come within five miles of their homesteads.

Sometimes there are many years between locust invasions. It rarely occurs that the whole State suffers at once. While the small visitations have been frequent, the destructive ones occurred at long intervals and over comparatively small areas.

Future Locust Depredations.—One reason for the destructiveness of locusts heretofore has been the small area in the thickest settlements under cultivation. The locusts seemed to select the cornfields and gardens for their feeding grounds. When the area under cultivation is trebled, the amount of damage which they can do will be more than one-half less. Another more potent agency against their increase and destructiveness is the increasing rainfall of the State. We have already seen how the wet season of 1877 destroyed the greater part of those that appeared that spring. During each coming decade the number of similar seasons will increase. The instincts of the locust will also prompt it to remain away from a region so hostile to its existence.

While, therefore, the presence of the locust in the trans-Missouri region is extremely undesirable, it is by no means the pest that it sometimes has been represented to be. Human energy and skill can in a large measure counteract their injurious effects.

MOLLUSKS.*

Though not directly connected with the main question of this chapter, yet, for convenience, the following brief enumeration of our moluscan fauna is given. There being no sea-coast, only land and fresh water forms are native to the State. Of these, the air-breathers are well represented. The Vitrianæ, a subfamily closely allied to the snails, are represented by seventeen species. Of the snails proper (*Helicinæ*), there are thirty species, the most abundant of which is the Spotted Snail (*Helix alternata*). There have been classified of the Pupinæ twelve species, of Succiniæ eight species, of Zonitinæ seven species, these last being distantly allied to the preceding group. The fresh water shells are even more abundant than the preceding land shells. Thus far, there have been found of these thirteen species of Limnæa, eight species of Physa, two of Bullimus, twelve of Planorbis, one of Segmentina, four of Ancyclus, two of Valvata, three of Vinipera, three of Melantho, two of Amnicola, two of Pomatiopsis and five Melanians. These fresh water shells having but one valve in a spiral are often all popularly designated as water snails. But the most abundant of all our fresh water shells are the so-called clams (*Unios* and *Anadontas*). Of the Unios there are at least sixty-seven species, of the Margaritanas two, and of the thin-shelled, muddy-bottom loving Anadontas there have been fourteen species found in the State. These are the numbers that I have identified, but as I have examined only comparatively small sections of our rivers, it cannot be possible that all the species came in my way. Many more species must, therefore, be added to our list. In fact, I have often waded in our rivers for miles without finding a single shell, and then, coming upon a hard or solid bottom of limestone, the bed appeared lined with Unios of many species. Before we know what our rivers contain of our molluscan fauna, they must be closely examined along their whole length, a task too severe for any one investigator.

*For a *specific* list of our Land and Fresh Water Shells, the reader is referred to the writer's Catalogue of the Land and Fresh Water Shells of Nebraska, published in Bulletin 3, Vol. III. of U. S. Geological Survey.

CHAPTER XIV.

Healthfulness.—Reserve Forces, and Probable Future of the Race in Nebraska.

IS Nebraska a healthy region? That is a question which is more frequently asked than any other by many classes contemplating removal to Nebraska. Among the special questions asked are: Do fever and ague, dyspepsia, consumption, etc., exist here? No spot on the globe is absolutely free from disease, but this State is singularly exempt from its severe forms. Fever and ague are rarely met with. The fact is that less malarial diseases exist here than in any other western State. When they do occur it is owing to limited local causes, or extraordinary exposure, and they are generally successfully treated by the simplest remedies. The bad cases that have been met were invariably contracted elsewhere, and came here in the hope of having the disease cured by our climate. They never were disappointed if they here gave nature a chance to exert its full health-making power on their bodies. Every effect must have a cause, and the cause of this general exemption from this class of diseases is probably found in the peculiar climate and surface conditions of the State. The general drainage of the State, as we have seen, is the best possible. Its general slope is east and south, the southeastern corner being the lowest. The rivers with the smaller streams that flow into them have high banks, on top of which the flood plains begin, and extend to a greater or less distance back to the bluffs where there is another rise to the general plain above. The rivers themselves are generally comparatively rapid, and their flood plains are rarely a dead level, but descend gradually in the direction of the main streams. And although often the flood plain is slightly higher next to the river than it is next to the bluffs, the water that tends to accumulate there is carried off by the lateral tributaries that join the main stream. As these smaller tributaries are met with every few miles, and often on an average every mile, the drainage of even the great majority of the bottom lands is complete.

Besides these favoring conditions the soil is principally Loess and Modified Drift and contains from sixty to eighty per cent. of silicious matter, very finely comminuted, which readily permits all water from rains and snows to percolate through it. Beneath the Loess unmodified Drift occurs, and this being made up of sand, pebbles and boulders, all the conditions for complete drainage are completely supplied. Even the black, rich surface soil, so wonderful for its fertility, contains silicious material in sufficient quantities to produce good drainage. The consequence of such inclination of the land and character of the soil and subsoil is that over large areas in the State standing water is unknown. Indeed, many citizens of the State, who have not traveled much, fancy that there is no standing water within its boundaries. There are, however, a few limited localities where swamps and bogs exist, such as a portion of the Missouri bottom in Dixon and Burt counties, and on small portions of the level prairies, in Clay, Webster, Fillmore and Saline counties. Even here the general elevation of these counties, and the constant movement of the winds seems to counteract the conditions of the surface that favor malarial diseases. Not only does the atmosphere seem to be constantly in motion, but is also comparatively dry. In summer and autumn the prevailing winds are south and southwest. In winter the prevailing winds are from the north and northwest. In spring the winds, as elsewhere, are exceedingly variable, and seem to be nearly equally divided, between north and northwest, and south and southwest. Often in the spring the prevailing winds are from the northeast. The air is always remarkably pure and generally clear. All these are conditions that are unfavorable to the production and propagation of miasmatic poisons.

An additional reason for the healthfulness of Nebraska might be the presence of an unusual quantity of ozone in the atmosphere. I merely suggest this as a partial explanation of this fact, as no single cause, but many combined, produce the healthfulness of a region. In the section on the *Atmosphere of Nebraska*, I have shown that the atmosphere of Nebraska is exceptionally full of ozone, caused probably by its highly electric condition, and the constant movement of electricity through dry air. As is well known, ozone is found in the east in perceptible quantities only after thunder storms, by which many suppose it to be produced. As here during much of the time, before as well as after thunder

showers, there is a perceptible quantity of ozone in the atmosphere, sufficient at least to respond to the Shœnbein test papers, it must have some effect on health. That its effects are salutary, especially in the destruction of malarial poisons, is the conviction of the best medical authorities.

The bane of some otherwise favored localities in America, is consumption. In Massachusetts, for instance, the vital statistics of the United States show this to be one of the commonest causes of death. Now, whatever may be the cause, Nebraska has a singular immunity from this and kindred diseases. During a residence of nearly fifteen years in the State I have not known of a single case of consumption to be contracted in Nebraska. There may have been such cases, but I have not been able to find any after diligent inquiry, or even to hear of such.* Many indeed have died of this disease in the State, but so far as I have learned the particulars of their cases, they all came into the State in an advanced stage of the disease, and sometimes here succumbed to it, only because of a want of proper care and remedies. On the other hand, hundreds come here with the disease who are cured by the climate alone. I know, for example, one young lady who was sent here from Philadelphia, apparently far gone with consumption, and reduced almost to skin and bone, and too weak to walk. She immediately commenced to improve, and in a year weighed one hundred and forty pounds. I admit that this was an extreme case and that she had the best attention and care, but it shows at least the possibilities in this direction of this climate with such adjuncts. This same lady was struck by cupid, got married, and is now the mother of three healthy, rosy children. Many more instances of a similar kind could be given.

I have known a great number of asthmatic subjects to come here, and soon all symptoms of the disease disappeared. Some years ago a young lady, a relative of my family, came to visit us from Pennsylvania. She had not been able, from difficulty of breathing, to lie down in her old home for six months before she came here. The first night in Nebraska she was able to lie down and sleep comfortably till morning. In a few months she seemed perfectly restored, which proved to be permanent for years after her return home. It is also curious that horses with the heaves lose all traces of this disease when

*Since writing the above, I have learned from Dr. Livingston of Plattsmouth, an eminent physician, that *one case* of consumption contracted in Nebraska came to his professional knowledge. This, however, is exceptional.

brought to Nebraska. Bronchitis also here readily yields to the influence of the climate. Inflammation of the lungs seldom occurs, and when contracted, readily yields to treatment. A volume could easily be filled with cures wrought by this climate on this class of patients. Of course the climate cannot perform miracles. No one should expect to be cured here who is in the third stage of pulmonary disease. Sick ones who come for health should be sure to go where they can get rest and be provided with home comforts. When scarlet fever and measles appear they are generally in their mild forms. They rarely appear as epidemics. As to typhus and cerebro-spinal fevers they are comparatively rare. Physicians of eminence assure me that the mortality from these diseases in other States is comparatively much greater than here.

The chief complaint that I have heard from citizens of Nebraska concerning its healthfulness is that it tends to produce rheumatism and nervous disorders. On diligent inquiry, however, I have almost invariably found that the great body of those complaining in this direction are such as have been insufficiently clothed during the colds of winter, or have exposed themselves to an extent or indulged in practices that would have produced these diseases in any climate. The tendency always is, in a new State, among the first energetic settlers, to great exposure. Many start for the West with barely enough to reach their destination. Often little is produced the first year on the homestead, and the old clothes are made to do duty the second year. Until the new homestead is fairly under cultivation (which sometimes takes several years), the new immigrant is often put to great straits for groceries and clothing. Of course, when the immigrant brings along money or stock to carry him over the first year, it need not be so, but thus far the majority have not been of this class. The circumstances, too, of a new country, stimulate to great risks and enterprises. Men will often start off on long journeys, through sparsely settled districts, ford streams, and in many other ways subject themselves unnecessarily to flood and storm. The consequence is that the principal diseases in some sections and seasons, have been rheumatism and neuralgia. I was once laid up with rheumatism, but it was after working in the Elkhorn River, with the water above my middle, when the thermometer was fifteen degrees below zero, trying to extricate my team which had broken through the ice. For this I could not blame the climate. Turkish baths soon took the rheumatism out of me. And yet with

all these circumstances favorable to contracting rheumatism, statistics show that most of the States have more deaths from this cause than Nebraska. Even California has double the number of deaths from this cause.

It has sometimes been objected that the extremes of temperature and of other conditions in Nebraska, must be unfavorable to health. There is, however, a great difference between an extreme and a destructive climate. That Nebraska has no destructive climate, is at once apparent, from the great variety of its vegetable forms and the exuberance of its natural animal life. Extremes of climate up to a certain point, while they may be injurious, and even destructive to the weak individuals of a species, rather benefit the normally healthy and strong. There is a greater variety of vegetable and animal life in the extreme climate of Nebraska than in the more moderate and equatable climate of England. It even favors those gradual changes of specific characters that advance the grade of vegetable and animal life. Compare, for example, the extremes of climate in Massachusetts and Nebraska. In the former, a warm, mild day is frequently changed to a cold one by a moisture-laden wind suddenly blowing from the northeast. These winds blowing there from the cold currents of the Atlantic, that come from the Labrador coast, chill the body to an extreme degree, and too often sow the seeds of consumption and other diseases which are the bane of that region. The character, therefore, of the northeast winds renders the climate there a partially destructive one. The northeast wind, on the other hand, in Nebraska, is dry in autumn and winter, and even in spring and summer, until the June rains come. And then they become laden with the moisture of the already warmed up waters of the Missouri and the Platte. Our moist winds here come from the Mexican Gulf, and are south and southwest, rather than north, east and northeast, as in Massachusetts. Our climate is therefore extreme, without being destructive. Its health conditions are the reverse of those in the Eastern States. Our extremes can be comparable to the Turkish bath, which stimulates into activity the functions of the body.

Nearly everyone who comes into the State feels a general quickening and elasticity of spirits. The appetite and digestion improve wonderfully. Mind and body are lifted up. All this occurs even with the execrably prepared food eaten in the most of the rural districts. For in most of the rural districts, hot biscuit, green with

soda, is still the form of bread usually eaten. Now this improvement in physical and mental condition cannot arise simply from change of locality. It must originate from our peculiarities of climate. I have myself felt in this State as I have never felt it elsewhere, especially when camping out, far away from settlements, and alone with nature and God, how luxurious existence was, and how pleasant life was intended to be. One needs but to go through the fever and ague stricken districts of other States, and then pass through the rural districts of Nebraska, to notice the contrasts between the sallow complexions found in the former region, and the hue of health and glow of spirits found here.

Owing to these facts, Nebraska must sooner or later become a health resort. In addition to the health producing properties of the climate, there are in various sections of the State mineral waters of high medicinal value. One of these is the artesian well on the Government square in Lincoln. It throws up a strong column of water from a depth of a thousand feet. It is used in two bathing establishments in the city. In the one at the Commercial Hotel, besides many others, over twelve hundred Turkish baths were given during the last (the first after opening) year. Some remarkable cures have already been performed here, especially on rheumatic and neuralgic patients: This water is also believed to be specific in many cases of dyspepsia, constipation, incipient scrofula, skin and kidney diseases. The water is strongly aperient.

The following substances I have obtained in making qualitative tests of the water. As the examination has not been completed, the results are only proximate:

Chloride of sodium (common salt), oxide and peroxide of iron, iron sulphuret, magnesia sulphate, bicarbonate of magnesia, bicarbonate of lime, sulphate of lime, sulphate of soda, sulphate of potash, oxide of manganese, etc.

There are other springs in the State containing various forms of sulphur, iron, magnesia, soda and lime. There is one, remarkable for its size and purity, near Curlew, in Dixon County. Unfortunately, our medicinal springs have not yet been systematically explored and examined, and until that is done, we cannot even approximate to their number and general quality, except in the case of the artesian well in Lincoln.

Reserve and Now Wasted Forces in Nebraska.

Owing to the almost constant movements of the atmosphere it can be much more extensively employed as a motive power than has yet been attempted. Wind mills are in general use now for pumping water and for motive power where little force is required. That it has capacity to do much more than this is evident when we formulate its force. A wind, for example, of three miles an hour moves 4.40 feet per second, and produces a pressure of about thirty-eight pounds for every square foot directly exposed to it. But winds that constitute a stiff breeze, traveling at the rate of twenty-five miles an hour, are not uncommon in Nebraska. This rate of motion equals 39.67 feet per second and produces a pressure of about 2,641 pounds for every square foot exposed to its action. Between these two velocities lie the movements of winds that could be depended on to propel machinery. Now, remembering that the movement of the winds is almost constant, and is felt in all situations, the amount of its wasted force is seen to be prodigious. Its use already, all over the west on farms and railroad stations for pumping water is a prophecy of its far more extensive employment as a propelling agent in the near future. Mechanical ingenuity will contrive a method by which the effect of the irregularity of the winds can be better overcome. The wind mills now used are already immeasurably better than those contrived only a few years ago. This improvement no doubt will continue until, like water in a mill dam, the wind itself can be stored up for future use. The mechanical engineer is already familiar with similar contrivances. Its intermittant character cannot always be an obstacle to its extensive use for driving machinery. It has one prime recommendation. It is cheap. Each year will therefore see a great multiplication of them.

A still greater source of force and energy and the the fountain of all the complicated movements on the earth is the sun. All the exhibitions of force, organic and inorganic, chemical or physical, the production of winds, currents, rainfall, the intricate causes that operate to produce varieties of climate—all these are dependent on solar radiation. Pouillet calculated that the earth received every minute from the sun 2,247 billion units of heat, which quantity, if transformed into mechanical force, "would raise 2,247 billions x 774 pounds to the height of one foot."

On the ocean alone "the sun raises during every minute an average of not less than 2,000,000,000 tons of water to a height of three and a half miles—the mean altitude of the clouds." In other words, to raise this quantity of water to the height of three and a half miles per minute, would require the continued exercise of the force of 2,757,000,000,000 horses per minute.

Here then is a power enormous beyond conception. Now such engineers as Ericson, have announced the opinion that an engine run by solar heat is practicable. He has even constructed an engine that gives uniformly a speed of 240 revolutions per minute, and at this rate uses up only a part of the steam produced by his solar generator. His machine includes a concentrating apparatus by means of which the feeble intensity of the sun's rays is increased to the degree that will answer to produce steam at a working pressure. He has also shown that such "a concentrating apparatus will abstract in all latitudes between 45° North and 45° South at least three and a half heat units for every square foot presented vertically to the sun's rays." "With one hundred square feet of surface, eight and two-tenths horse power would be developed during nine hours between the above latitudes." In the latitude of Nebraska it could be used for at least ten hours on each day of sunshine.

Monchat has advanced even farther than Ericson, and exhibited a solar engine at the Paris exhibition that attracted the attention of engineers from all lands. It received one of the medals of the exhibition.

"The time will come," says Ericson, "when Europe must stop her mills and factories for want of coal. Upper Egypt, then, with her never-ceasing sun-power, will invite the European manufacturer to remove his machinery and erect his mills on the firm ground along the sides of the alluvial plain of the Nile, where sufficient power can be obtained to enable him to run more spindles than a hundred Manchesters." Now it is true that the coal fields of the United States will not be exhausted for many thousand years, but the transportation of coal is costly, and there is no reason, if solar engines are possible, why the sections that are adapted to them should not use them, especially if their cost is much less than those run with coal.

Now then, in Nebraska, as if it was a region specially reserved for the exhibition of the adaptability of the solar engine to the uses of civilization, there is a remarkable amount of sunshine. As we

have seen, even most of the rainfall occurs at night. Only during portions of June and July, and occasionally the last weeks in May, are there any continuous rainy or cloudy days. During the remainder of the year, the sky is remarkably clear. All the stupendous sun force that is here exhibited is now wasted, except the minute portion that is used for the processes of organic life and the production of the winds and rains. These wasted energies must, in the nature of things, hereafter be utilized. Some time in the future, the manufacturing establishments of the East can be run here without coal or water power. Probably the East, because of its murky skies, can never change its motive power. Coal and water power will always be in demand there. Here the now wasted energies of the sun will be utilized to produce the motive power needful to manufacture the cotton, woolen and other fabrics which a population of many millions will consume.

Probable Future of the Race in Nebraska.

This question often suggests itself in a newly settled country; what kind of an abode is this for humanity? Will the race here go into decay, remain stationary, or advance? It is taken for granted that that people is the most advanced where there is the greatest happiness of the greatest number. When the causes that produce a great people are sought, we invariably find that they are complex. Among them, however, we always find some of the following: Good government, good climate, fertile soil and a good geographical position. Nebraska possesses all of these, as we have seen by the preceding discussions, in an eminent degree. That environment helps greatly to make character is now universally admitted. The Englishman of New England, the Dutchman of New York, and the German of Pennsylvania are all exceedingly different from their ancestors of two centuries ago, and from their distant kinsmen in Europe at the present day. The new world with its new conditions has made a new order of men. Wherever there is freedom character is multiform. In the older States the families that live on the ridges, on naturally barren soil, are inferior in culture and social life to those that live in the fertile valleys. The latter occupy lands that yield them a better return, more wealth, and as a consequence there is more time for study, more means for travel, and for the cultivation of the amenities of life. It requires more than mere physical labor to better the conditions

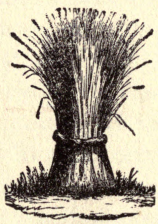
of a people—it takes money, leisure, incentives to study, and good climatic conditions. The mass of those communities that have been most distinguished for a high civilization, and for leading the thought of the world, have occupied regions highly favored by nature. Witness for example, Mesopotamia, Palestine, Egypt, Hindoostan, Greece, Italy, etc. As already observed Nebraska is the peer in many particulars of the best of these regions. It has no sea coast, but its soil is one of the best, easiest worked and most lasting in the world. It has no lofty mountains, but it has a variety of landscape which for quiet beauty is unequaled. Its atmosphere is exceptionally clear and pure, and the extremes of temperature are only such as are most promotive of good health and energy of character. While there are no great lakes, there is a superabundance of fresh water in creeks, river, springs, and rills. Its health conditions never lead to stolidity, but to intellectual activity.

There has not yet been time for this climate to exercise its full influence on the people. That it will, in a marked and happy way, affect the people in the course of time, is as certain as any other fact in nature. The true Nebraskian does not yet exist, because even if born here he is yet too much affected by entailed peculiarities. And the great body of those that are living here were born and married in the east. Our skies, rivers, soils, surroundings are all moulding the people, but they have not had time to perfect the work. Look for example at the type of people that the States bordering on the upper Mississippi have produced. The true type of American character is no longer the east, but the west. And this is true because while in the east there is more wealth and outside polish, in the west there is more originality, more independence in manners and opinions, more freedom from restraint and more sincerity. The west has already so affected the life of the people that a young man coming here from the east will be more ambitious, more active, more successful, more courageous, and more of a man than if he had remained in his native State. Absence from the sea-board does not lessen but rather increases western energy. The railroad cultivates the mind, requires as high an order of character, to say the least, as the sea. As high an order of ability is needed to work a railroad train as to manage a ship. A brakesman in character is more than the peer of the sailor. The west is checkered with railroads which make the people sociable, as well as carry their

products to distant regions. And if, as some claim, there is less devotion to hard physical labor, there is, on the whole, more reading, more thinking, more intelligence.

But the Missouri Valley is greatly different from the Mississippi. In its upper portions at least, there are still clearer skies, a dryer atmosphere, more freedom from malaria, and is more elevated. Here the American character is subjected to new influences and will be still farther specialized, and will necessarily reach a still higher stage.

What then may we legitimately expect of the people in Nebraska in the future? We have a right to expect that our school system will reach the highest possible stage of advancement—that the great mass of the people will become remarkable for their intellectual brightness and quickness. Along with this mental development and synchronizing with it, there will be developed a healthy vigorous and beautiful race of men and women. Art culture will then receive the attention which it deserves. Music, painting, and sculpture will be cherished and cultivated for their own sake. The marvelous richness of our soils will give a true and lasting basis for prosperity and wealth. For be it remembered that agriculture in all its branches, endures the tests of time better than any other industry. It is also the best school of virtue for a nation. Happy the children that are trained to industry on a farm. More men and women of high character and endowments come from the farm, than from any other station. It is nearest to the heart of nature and nature's God. Though yet in its infancy, all these agencies for the prosperity and well-being of Nebraska are steadily at work, and in the fullness of time will blossom into fullfilment of its early promise.



PART SECOND.—GEOLOGY.

CHART OF GEOLOGICAL HISTORY.

PREPARED BY

SAMUEL AUGHEY.

IN PART ADOPTED FROM J. S. NEWBERRY.

ERAS.		AGES.	PERIODS.	EPOCHS.	STRATA. (N. AMERICA.)	STRATA. (NEBRASKA.)
PSYCHOZOIC.	Age of Angiosperms and Palms.	AGE OF MAN.	HUMAN.	Historical.	Cave Deposits. Peat. Alluvium.	Alluvium. Peat.
CENOZOIC.	Age of Angiosperms and Palms.	AGE OF MAMMALS.	QUATERNARY.	Terrace. Champlain. Glacial.	Terraces. Loess. Saxicava Sand Forest Bed Champlain Clay. Erie Clay. Glacial Drift.	Terraces. Beaches. Loess. Iceberg Drift. Kames Forest Bed. Glacial Drft. Champlain clay. Blue clay.
			TERTIARY.	Pliocene. Miocene. Eocene.	Pliocene. Miocene. Eocene.	Pliocene. Miocene. Wanting.
MESOZOIC.	Age of Angiosperms and Palms.	AGE OF REPTILES.	CRETACEOUS.	Upper Cretaceous. Middle Cretaceous. Lower Cretaceous.	Laramie Group. Fox Hill Group. Pierre Group. Benton Group. Dakota Group (Wanting?)	Not Exposed. Pierre Group. Niobrara Group. Benton Group. Dakota Group Wanting.
	Age of Cycads.		JURASSIC.	Wealden. Oolitic. Liassic.	Jurassic Strata, Colorado, Utah, Nevada, California, Sonora.	Wanting
			TRIASSIC.	Keuper. Muschelkalk. Bunter-Sandstein	Triassic Sandstones, Marl. Coal, &c. Atlantic Coast New Mexico. Arizona, California, Sonora, &c.	Wanting.

ERAS.		AGES.		PERIODS.	EPOCHS.	STRATA.	
PALÆOZOIC.	Age of Acrogens.	CARBONIFEROUS, OR AGE OF COAL PLANTS AND AMPHIBIANS.		PERMIAN.	Permian.	Permian Dolomites.	Permian Dolomites. Permo Carboniferous.
				CARBONIFEROUS.	Upper Coal Measures. Lower Coal Measures. Carb. Conglomerate.	Upper Coal Measures. Lower Coal Measures. Carb Conglomerate.	U. Coal Measures. Not Exposed. Not Exposed.
				SUB CARBONIFEROUS.	Upper Sub-carboniferous. Lower Sub-carboniferous.	Sub-carb Limestone. Sub-carb. { Shales and Sandstones.	Not Exposed.
		DEVONIAN, OR AGE OF FISHES.		CATSKILL.	Catskill	Catskill.	Not Exposed.
				CHEMUNG.	Chemung. Portage.	Chemung Group. Portage Group.	
				HAMILTON.	Genesee. Hamilton. Marcellus.	Genesee Shale. Hamilton. Marcellus.	
	Age of Algæ.			CORNIFEROUS.	Corniferous. Schoharie. Cauda-Galli.	Carniferous. Schoharie. Cauda Galli Grit.	
				ORISKANY.	Oriskany.	Oriskany Sandstone	
		SILURIAN, OR AGE OF MOLLUSKS.	Upper Silurian.	HELDERBERG.	Helderberg.	Helderberg.	Not Exposed.
				SALINA.	Saliferous.	Onondaga Salt Group.	
				NIAGARA.	Niagara. Clinton. Medina.	Niagara. Clinton. Medina.	
			Lower Silurian.	HUDSON.	Hudson. Utica.	Hudson River Shales. Utica Shales	Not Exposed
				TRENTON.	Trenton. Chazy.	Trenton Chazy Limestone.	
				CALCIFEROUS.	Calciferous.	{ Quebec Group. Calciferous Sandrock.	
				PRIMORDIAL.	Potsdam.	{ Potsdam Sandstone. St John's Group.	
EOZOIC.		EOZOIC.		EOZOIC.	Huronian. Laurentian.	Huronic System. Laurentian System.	Not Exposed

PART SECOND.—GEOLOGY.

CHAPTER I.

CARBONIFEROUS AGE IN NEBRASKA.

Preceding Conditions.—Carboniferous Age Proper.—Age of the Nebraska Rocks.—A Different Opinion.—Section at Nebraska City.—Coal Features of the Carboniferous Age in Nebraska.—Vegetation of the Coal Age.—Animal Life of the Coal Age.—Climate of the Coal Age.—Permian Age.—Its Transition Character.—Character of the Permian Rocks.

Preceding Conditions.

IT does not enter into the plan of this work to treat of the early condition of the globe, or even to discuss the earlier periods of Palæozoic times. Suffice it to say that our globe was once companion star to the sun, and that after it had cooled down sufficiently, the oceans were at first probably universal. Then came a nameless period when lofty uplands were formed towards the far north that supplied the materials for the old sea bottoms that were afterwards uplifted and became known as the Archæon highlands of Canada and the United States. The two well marked divisions of these old deposits are known as Laurentian and Huronian rocks. As the rocks of these ages still left in Canada are forty thousand feet thick, and at least as extensive in the Rocky Mountains and the Sierras, and still greater in Bohemia and Bavaria, after being subjected to numberless ages of erosion, the time represented by their deposition was greater, probably, than the whole of geological history since their close. So far as we now know, during all this immense age there was no dry land in Nebraska.

Then followed what the geologists call Palæozoic times, because of the antique or old life form of all the animals and plants in the old world. The earlier portions are known as the Silurian ages, during which invertebrate life was dominant, and the continent was

growing and extending southward from its Archæon nucleus. The next age, called often the age of fishes, and also known as the Devonian, followed, but neither in this or in the preceding Silurian was any dry land in Nebraska. By the close of this age, however, the continent in its southern extension had reached the south line of what is now New York, and many islands also existed still farther south, and in some places west. The Appalachian region seemed to have been rich in low islands, covered with a colossal vegetation. The sub-carboniferoos period, which had such a remarkable development in some sections of Illinois, Kentucky, Iowa and Missouri, and which was the stage preparatory to the carboniferous period proper, is not represented by any known deposits in Nebraska.* Even the millstone grit so common in the East, under the coal, has not here been found. Whether it exists at all in this region can only be ascertained when borings or shafts reach its geological equivalent. We come now to

The Carboniferous Age Proper.—This is a geological age of the most absorbing interest, because of the general character of the time, and because during its progress the first dry land appeared in Nebraska. The carboniferous age was one of the most wonderful in all the history of the globe, for during its progress the thickest, most extensive and most valuable of all the coal beds were formed. It has excited the most profound interest alike of the political economist, the statesman, the chemist and the geologist.

To understand the probable history of geological events in Nebraska during this period, let us look at the oldest coal beds that are nearest to us. These are the beds along the Des Moines River and some of its tributaries extending westward within from seventy-five to one hundred miles of the Missouri. The coal here, which Dr. White regards as of Lower Carboniferous age, is from one to seven feet in thickness. Worthen first, and then Dr. White to a much greater extent, investigated these beds. Meek also carefully re-examined them. Subsequently I passed over the same region, attempting as Meek and White had done before me, to estimate the thickness of the rocks that lapped over the coal bearing strata as far west as the farther or Nebraska shore of the Missouri. Meek's objective point was Nebraska City, and mine was Plattsmouth. I shall therefore use Meek's observations to supplement my own.

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*The opinion of Marcou and Geinitz (Bulleton Geological Society of France, XXI., etc., New Series), that some of our Nebraska rocks are sub-carboniferous, was shown long ago, by Meek, to be a mistake.

At and near Des Moines there is no millstone grit such as is found at this horizon farther east, and therefore the lower coal beds rest, as White and Meek have observed, on the sub-carboniferous rocks. West of the Des Moines River, as also shown by these geologists, the coal measures belong to a higher geological horizon, and most probably to the middle series, though there is no serious palæontological or physical break between these and the lower rocks of this age. On going southwestward from the Des Moines, in the deep valley of Middle River, which lies about two hundred and fifty feet below the plain, the rocks here dipping slightly towards the southwest. Here the increasing thickness of the upper coal measure beds can be distinctly seen. The upper bed of the middle series is last seen at Winterset, at the very bottom of the valley, and all the beds above for two hundred and fifty feet belong to the still higher series, consisting largely of heavy beds of light yellow limestone, sandy micaceous shale, black laminated shale, blue, drab and reddish clays, and occasionally a few inches of impure coal. In these upper beds are found almost identically the same fossils as on the Nebraska side of the Missouri. Among these is the curious fossil (*Fusilina cylindrica*), which is so often mistaken for fossil rice or wheat. Twenty-three additional fossils are characteristic of these two sections. On leaving this valley, no more exposures of the middle series are visible, the inclination of the strata towards the southwest taking these beds below the deepest eroded valleys. At various points, however, between this place and the Missouri, opposite Plattsmouth, the upper beds are exposed, and can be readily identified by their contained fossils. Dr. White, also, who made a critical examination of the whole region, is confident that he can identify the upper members of the Winterset exposures in the Missouri bluffs on the Iowa side between Nebraska City and Plattsmouth. However that may be, there is no doubt, judging from the evidence of fossils, and the physical character of the rocks, that the series on both sides of the Missouri, between the south line of the State and Omaha, belongs to the upper series of the coal measures. According to Dr. White, the nearest visible series of the middle coal measures to the Missouri is at a point in Iowa nearly due east from Blair, at a distance of about sixty miles. Having also myself gone over and carefully examined these exposures, the conviction was forced on me that White and Meek are proximately correct in their determinations of the horizons of these rocks. It is therefore definitely established that on the Nebraska side, as far as

the coal measures extend from above Omaha, near old Fort Calhoun, to the southeast corner of the State, the rocks are of Upper Carboniferous Age.

A Different Opinion.—In 1866 Prof. Geinitz, of Dresden, made a report on carboniferous fossils which were collected in Nebraska mainly by Prof. Marcou, in which he expressed the conviction that the rocks along the Missouri belong in part to the Lower Carboniferous and in part to the Permian. He evidently made this mistake, as Meek has shown, by examining an imperfect series of fossils, and by a lack of acquaintance with the range of species in the Palæozoic of this country.* In order to exhibit the facts on which he bases these references the following section is given as taken at Nebraska City.

Section Exposed at Nebraska City Landing.

	NATURE OF STRATA.	Thickness.
	Loess deposit, Grayish yellow........................	90 feet.
D.	Yellowish-gray micaceous, soft sandstone, laminated, sometimes ripple-marked, except about 14 inches of sometimes hard and compact stone at bottom, with fragments of plants..	10 feet.
C.	Drab, ash, and lead-colored, and brownish clays and near the middle a ten inch, hard bluish-gray, clayey, limey layer, becoming rusty on exposure. Fossils numerous............	39 feet.
B.	Several beds of hard light grayish, and yellowish lime stone in layers of from five to twenty inches thick, with soft, marly clay seams and partings. Fossils numerous especially fusilina, etc..........................	13 feet.
A.	(*a*) Lead—grayish and greenish clay, four feet. (*b*) Reddish brown ferruginous, slightly gritty, indurated clay, four feet exposed above high water..........	8 feet.
	Total below drift .. .. †	70 feet.

* See Meek's report in "Hayden's Final Report on Geological Survey of Nebraska," p. 83.

† This section is slightly different from that of Meek and Marcou, because taken a little below theirs.

Now the thirty fossils in bed 3, and the sixty-six in bed B, of this section are all of them in the Illinois, Indiana, and Missouri coal fields characteristic of the Upper Carboniferous and not of the Permian, though some of the genera are known to pass into it. They cannot therefore be Permian, as Marcou and Geinitz supposed. The beds, on the other hand, at Bellevue and Omaha which they referred to the Sub-carboniferous, contained the characteristic organic forms that characterize the true Upper Carboniferous everywhere else in this country. These distinguished foreign geologists attempted to generalize on American rocks by the principles that interpret aright European geology, and hence they were led into a blunder. Here, almost universally the vertical range of species is much greater than in Europe. American geology must be studied independently of European systems, or at least cannot be interpreted by them.

Coal.—Thus far no thick workable beds of Coal have been found in our carboniferous measures. The question rises whether there is any probability of any valuable beds being found anywhere in the State. Truth compels the admission that such a result is uncertain and even doubtful.

Mr. Broadhead, one of the State Geologists of Missouri, has long since reached that conclusion with reference to the Upper Carboniferous measures of that State, where, owing to changes of level and numerous natural exposures a great thickness of these beds had early and easily been examined by him. He gives sections through these rocks extending to a depth of nearly two thousand feet before reaching coal two and a half feet thick, all above being only from a few inches to two feet in thickness. Dr. White's numerous sections observed in many places west of Winterset to the Missouri show clearly that the upper series thicken westward and southwestward, and not by the super-position of newer beds, but simply by the thickening of those seen at that place. At a few places a considerable thickness of these upper beds have also been examined in Nebraska along the Missouri, and with the same result as in Missouri and Iowa. Mr. Croxton, as early as 1865, made an artesian boring near Nebraska City, to the depth of three hundred and forty-four feet. Shales, limestones, micaceous sandstones and calcareous sandstones constituted the materials passed through, but no indications of coal were met until at the depth of one hundred and eighty-nine feet, a bed fifteen inches thick was struck. None was

struck after that. An artesian boring has also recently been made near the west end of the Union Pacific Railroad bridge at Omaha, to a depth of seven hundred and fifty feet. This point, which is the lowest yet reached along the river in Nebraska, by borings, was struck without encountering any beds of coal. For this depth therefore these upper measures, at least at this place are barren. At Lincoln, on the public square, the artesian boring was put down to the depth of a trifle over a thousand feet. A little before this point was reached the contractor, Mr. Eaton, reported going through a thirty inch bed of coal. As Lincoln is at least one hundred and eight feet above the level of Omaha, it is clear that the boring of the Union Pacific well at that place did not reach the horizon of the coal bed reported by Mr. Eaton. This bed of coal is probably in the lower coal measures and is the geological equivalent of the Des Moines beds. These Des Moines coal beds or their equivalent would therefore be struck at Plattsmouth somewhere between eight hundred and one thousand feet below the surface. According to my own calculations made in traversing the space between Des Moines and the Missouri, it would be about nine hundred feet. Prof. Meek believed that Omaha, where the upper coal measures are exposed at a lower horizon, borings would strike the geological equivalent of the Des Moines beds under one thousand feet, and at still greater depth further down the river. Owing to the facts developed by the artesian boring at Lincoln, it is probable that all these estimates were too high and that these Des Moines coal beds or their equivalents would be reached between Plattsmouth and Omaha at a depth of between eight and nine hundred feet.

The question then returns whether there are or can be no good workable beds of coal anywhere in these Upper Measures. The old Nuckolls coal bed, worked near Rulo, in Pawnee County, in Otoe County, and at several places in Cass and Johnson counties, ranges from eight to eighteen inches in thickness, and in places is a fair article of coal. The bed at Aspinwall, which is from twenty-two to twenty-four inches thick, is not certainly its geological equivalent. The same remark applies to a comparatively pure bed of light coal, from eighteen inches to two feet in thickness, on the Indian Reservation south of Rulo, near the State line. But no beds thicker than these have yet been found in these Upper coal measures, and as we have seen, the probabilities are against their existence.

If extensive basins of coal existed in them they probably would have been observed in Missouri, where they have been more thoroughly explored. With the Lower Coal Measures the case stands different. These are the coal bearing measures in Iowa and Missouri, and at least in one place (Lincoln), where they have been penetrated, a respectable coal bed was reported. All the chances then are in favor of finding large workable beds at this horizon. This is a question that should speedily be settled at public expense. If there are workable beds, the State should have the benefit of it as soon as possible. An artesian boring within six miles of the Platte River, near its mouth, to a depth of one thousand feet; another near Nebraska City and one near Rulo, would settle this question*.

Features of the Carboniferous Age in Nebraska.—All the students of geology admit that the Carboniferous age was a very long one—an age whose length could not be measured by thousands, but by millions of years. During the greater part of this great age, Nebraska was occupied by an arm of the ocean. Sometimes for long periods this sea was turbulent, as is indicated by the rocks, which so generally change their character within a few miles. A sand rock often, when followed for a few miles, changes to a shale, then to indurated variously colored clays, and then a conglomerate. Owing to this feature, the exact equivalent of the rocks at widely different stations is hard to distinguish, except along river bluffs, where the strata are exposed for long distances. The limestones having been formed in deep water, are more constant in character over extensive areas, but even these sometimes exhibit sudden transition characters. They present various forms and colors, such as silicates of lime and magnesia, nearly pure limestone, yellow, gray and white limestone, and shaly, rotten limestone. Many of the shales and conglomerates exhibit the character of off-shore deposits. If future borings brings to light beds of coal in the lower coal measures, it will be proof of the existence at that time of dry land near by, and of a boggy, swampy condition on the sites where they are now found. As one foot of bituminous coal represents from nine to eleven feet of original peat, and many centuries are required for the formation of such an amount of vegetable matter, and as these beds represent only an infinitesimal amount of the time during which the events of this age were in progress, it is

*See on the subject of this section, Meek's Report in the Hayden Surveys.

additional proof that its length was beyond all calculation. But during its progress, deep seas and shallow seas, quiet seas and turbulent seas, and vast bogs and swamps near to slightly elevated land masses, in turn predominated.

Vegetation.—The vegetation of the Carboniferous age was remarkable for its luxuriance and its antique form. In organization it was below the high modern types, but many of its forms were exquisitely beautiful, synthetic and complex.

The conifers that then existed, and which were the most advanced in type of all the vegetable forms, flourished mainly on the uplands. The most of them were closely related to Araucarian pines, which still flourish in low latitudes and mainly south of the equator. The fern family, of which a few diminutive representatives still linger among us, culminated in that age, many species growing to the dimensions of trees, and with a gracefulness and beauty unsurpassed by any vegetable form at the present day. Many hundreds of species flourished over the forming coal fields of the west. In fact, one-half of the coal plants were probably ferns. The calamites of that day, which grew to tree size, were also abundant. The scouring rushes (*Equisetae*), which seldom reach over one or two feet in height, are their modern representatives. Two great orders, more abundant in the number of individuals than any others, the Lepidodendrids and Sigillaria are no longer in existence. They, along with the calamites, formed a large part of the material of the coal. The Lepidodendrids had a dense bark, underneath which was a dense mass of loose tissue, through the centre of which ran a small cylinder with a distinct pith. Such a structure unfitted it for anything like bearing timber, but adapted it most admirably, when flattened down, for flakes of coal. The sigillarids, with "trunks fluted like Corinthian columns," and ornamented with seal-like impressions in vertical ranks, and "with few large branches and long needle-like, tapering leaves," were unfitted for anything except to minister to the beautiful and to make coal. It is remarkable that in that distant past, long ages before man appeared, the jungles and forests of the globe were as remarkable for beautiful forms as the woodlands of to-day. The Deity, however, was there to enjoy it.

Animal Life.—Animal life during this age was abundant, though, as in the vegetable kingdom, the forms were mostly antiquated. One of the most abundant of all in individuals was the curious little

animal, already referred to, and which is frequently called fossil wheat or rice. It is, however, a lowly animal, classed with the protozoans, and known as *Fusilina cylindrica*. The shell is small, half cylindrical and bluntly pointed at the end, and averaging about the size of a grain of rice. Its shell is composed of seven or eight closely coiled whorls. Unlike its condition in Europe, it here ranges all through the coal measures. It is questionable whether it is anywhere in America as abundant as it is here in Nebraska. In Johnson County in many places around Tecumseh, it constitutes almost the entire fabric of many rocks, often from four to ten feet in thickness. It is often present in enormous numbers in shale, and where it is decomposed, hundreds can be picked up, already by the decomposition of the matrix lying loose and cleansed ready to be placed in a cabinet. All along the carboniferous exposures in Nebraska, it is abundant, in limestone, sand stone and shale. The massive compact limestone from Stout's quarry, on the north side of the Platte, at South Bend, contains immense numbers of these Fusilina, which gives the rock great beauty when polished.

Corals, which are now confined to low latitudes, were abundant in Nebraska during Carboniferous times. Five species have thus far been identified here. The most characteristic grew into a curious form remotely resembling a short ram's horn. It is known by the name of *Campophyllum torquium*. A loose bed of shale in the bluffs at Rock Bluffs contains an immense number of them.

The Crinoids were represented by seven species at least, and some of them existed in great numbers. While the heads of these sea lilies, as they are sometimes called, are only occasionally found, owing no doubt to their original fragile character, their screw-like stems are abundant in all the rocks.

As elsewhere during Carboniferous times molluscan life flourished here. The Polyzoa were represented by eight, and the Branchiopods by twenty six species, of which eight were Producti.* Among these one known as *Productus Semireticulatus* is quite large and was one of the most abundant animals in these old Carboniferous seas. Those known as *P. longispinus*, *P. prattenianus*, and *P. Nebraskensis* are also abundant. Two species of thin flat shells called *chonetes granulifera* and *C. glabra*, make up the almost entire mass of some limestone rock at Plattsmouth and other places along the Missouri. No shell is perhaps so widely dispersed as the one

*The Producti are now mostly classed with the Articulata.

called *Athyrus subtilita.* It occurs in almost every layer of the Carboniferous rocks and of many sizes. Among the Spirifers the most abundant and beautiful is *S. cameratus.* Lamellibranchs (two valved shells with gills in laminæ on the sides) were represented in Nebraska during this age by at least forty species. The Gasteropods (one valved, like snails. Belly creepers) were abundant in individuals and species, not less than eighteen forms having thus far been identified. Of chambered shells there was one strait species (*Orthoceras cribrosum*) and two coiled ones, (*Nautilus occidentalis* and *N. ponderosa*).

Of the five species of Crustaceans found fossil in these rocks three are trilobites of the genus Phillipsia.

Vertebrate life so far as is now known was represented here in Carboniferous times principally by fishes, of which eight species have been described by Orestes St. John. Many more have been found which have not yet been identified.

Climate.—The vegetable and animal life of the Carboniferous Age indicates that its climate was not subject to extremes, at least during the epochs when the rocks were deposited, whatever it may have been during the transition intervals. It was neither intensely hot nor cold. It was just such a climate as a constantly murky, cloudy atmosphere, over semi-continental levels and flats would naturally produce.* Tyndall has shown that a slight addition to our atmosphere of carbonic dioxide would raise its mean temperature many degrees. If our atmosphere then, at that time, as many geologists believe, contained the greater part of the coal deposits of the globe in the form of carbonic dioxide gas, it would have made it a huge hot house. This would account for the uniformly warm temperature that then existed far into the arctic regions.

Close of the Carboniferous Age.

In the eastern portion of the continent the Carboniferous Age was evidently closed by the Appalachian revolution. This great uplift was evidently continental in character, the level of the land on each side being raised along with it. This was no sudden convulsion. The Appalachians commenced to rise long before the close of the age and during its progress a point was reached when the old conditions were passed and new ones inaugurated. Vege-

*The theory that the Coal Age was produced by a period of high eccentricity of the earth's orbit, during times similar to the subsequent glacial ages is best discussed in Croll's work on "*Climate and Time.*"

table and animal life partook of the change and the whole movement inaugurated or constituted

THE PERMIAN AGE.

This age was the last volume in the history of Palæozoic life. The great Appalachian revolution was only partially completed, for the upward movement still continued. The peculiarities of the coal age had ceased, but its impress was left on Permian times. While the upward movement was advancing towards completion, at many places, especially in Europe and Asia, around the borders of the old coal fields, depressions still existed for extensive seas which received the sediments that entombed and preserved the organic remains of the age. Hence we have records of the earlier part of the age, but none of its latter portion, because the continents reached such an elevation that all the seas were drained, and no place was left to stow away the debris and worn out life of the period. The process of uplifting, therefore, was continued until the continent was raised far above its present level, during which none of its memorials could be preserved. The whole latter portion, therefore, of the Permian, a portion of time incalculably long, is a lost interval in geological history. For the first time in geological history the conditions were favorable for the complete drainage of the continent. Lofty mountains produced great rivers and steep inclinations towards the sea. Clear skies took the place of murky ones in the previous age. The seasons gradually became more changeable and varied. The old vegetable and animal life was not adapted to these conditions and hence it had to change or perish. As a matter of fact during this last interval occurred those mighty changes in the fauna and flora of the globe which transformed the Palæozoic life into the middle or Mesozoic world.

In the United States the Permian deposits occur mainly in Kansas and Nebraska. Here the western boundary of the Permian passes a little west of south, a few miles east of Lincoln, extending to Beatrice, and thence into Kansas. Opposite Lincoln it is only a few miles broad, but widens going southwest and through Kansas. Towards the west at Lincoln and Beatrice it passes under the Dakota group of the cretaceous. It is, however, as already intimated, only the lower Permian that is here represented. In the earlier Permian this portion of the continent was not raised above the old carboniferous seas, and of course it received the sediments brought down by the rivers and creeks from lands sloping towards

the west on the east, north and northeast. These lands were partially the upraised carboniferous sea bottoms. As elsewhere, the progress of elevation left the latter Permian here without any memorials of its existence.

It is possible that in some section of the old world, not yet geologically explored, remnants of this as yet lost interval will be recovered or discovered. If so, we will no longer be compelled as now to people this age with the changing life that then must have existed. The old notion of cataclysmic changes of sufficient force to destroy all life, and subsequently entirely new creations has long since been abandoned. "Nature rarely turns a sharp corner." Life has not ceased on the globe since it began. In obedience to new conditions it has ever been changing into new forms. And in no period of world history have the transformations been so great as during the Permian Age.

Character of the Permian Rocks.—Near and around Beatrice there are many exposures of yellowish, occasionally bluish magnesian limestone, full of geode cavities lined with calc spar.* This rock is arranged in layers from four inches to two feet thick; and the whole series of strata are from twelve to twenty feet thick. Below this there is a bed of yellow compact limestone from eighteen inches to three feet thick. Next below, there is a thickness of from eight to twelve feet of a dark grayish clayey limestone, also full of geode cavities, lined with crystals of calc spar, and sometimes of silica or silicate of lime. This stratum often becomes light colored on exposure to the air. Occasionally it becomes massive cream colored limestone. Wherever, therefore, such beds as thus described are found in Nebraska, bordering the Upper Carboniferous rocks, they invariably indicate our Permian deposits. Towards the east, in Pawnee County, they run out, as the carboniferous then becomes the surface rock, which, on the contrary, in a westward direction, run under the Permian. Above the first of these Permian rocks there is a bed of variegated clay, and sometimes of potter's clay, whose geological age is uncertain, but which probably belongs to the Dakota Group of Cretaceous rocks, which comes in next above. This Dakota Group, itself, can be recognized by its dark gray, brownish and red sandstones, which around and westward from Beatrice overlies the Permian.

*These geode cavities are now generally believed to be formed by cavities left in the original sediments by covered up sponges, that subsequently decayed.

CHAPTER II.

MEDIÆVAL OR MESOZOIC TIMES IN NEBRASKA.

Absence of Deposits of the Triassic and Jurassic Periods.—Cause of this Absence.—Length of these Periods in Nebraska.—Cretaceous Period.—How it Originated.—Divisions of the Cretaceous.—Dakota Group.—Its Character, Extent and Remarkable Flora —Origin of this Flora.—Climate of the Dakota Group Epoch.—Fort Benton Group.—Its General Character.—Length of this Epoch, and its Vegetable and Animal Life.—Niobrara Group Epoch.—Extent of its Deposits, and General Character.—Vegetable Remains.—Animal life of this Epoch.—Rhizopods, Mollusks and Fishes.—Reptiles, their Great Abundance and Peculiar Character.—Final Disappearance of this Reptile Fauna.

TRIASSIC AND JURASSIC PERIODS.

THERE are no known deposits of the Triassic and Jurassic periods in Nebraska. The deposits of the next or Cretaceous period rest directly on the Permian. Two explanations of this fact are possible. First, the Triassic and Jurassic deposits may once have been here, and were removed before the Cretaceous was laid down by denudation. Or, second, this region may have been a land surface during these periods. This latter view seems to be the most probable, and best explains all the facts of this portion of our geological history.

We have already seen that the Carboniferous Age was brought to a close by an upward movement of the continent, and that this movement continued through the Permian, until much of the previous water surface was drained, and made it impossible to preserve the memorials of its latter history. The same events that prevented the preservation of the memorials of the Permian, would, if continued, prevent the deposition of Triassic and Jurassic rocks. With a large degree, therefore, of certainty, we may rest assured that during these periods Nebraska was an extended land surface, and if so, there must have flourished here for countless centuries the peculiar vegetable and animal life of those times.

Length of the Trio-Juro Periods.—The length of the Trio-Juro periods can be ascertained only relatively. Not even an approximate estimate can be made, but all geologists admit that they were

very long periods. In the Rocky Mountains the Triassic deposits lie in unconformable masses, directly on or against the Archæan islands that form the back-bone of the continent.* Here the Triassic forms a series of sandstones from three hundred to one thousand feet thick, which are loose, friable sediments wherever there is an approach to a horizontal position. "On approaching the Archæan, the Trias always is composed, or largely made up of conglomerates, the materials of which were derived from the shores against which they abut."—Clarence King. Towards the eastern part of the Uintas the Trias thicken still more, reaching finally a depth of from two thousand to twenty-five hundred feet.. Still farther westward the Trias diminishes in thickness and increases in compactness and the quantity of conglomerates. From these facts Clarence King concludes that there was a land mass towards the west, during this period from which the materials that enter into its deposits were derived.

Overlying the upper beds of Triassic rocks, which are intercallated with gypsum and dolomitic limestone, are the Jurassic beds, which are first met in the eastern flank of the Colorado range. Here they are only two hundred and fifty to two hundred and seventy-five feet in thickness, and increase westward, until, on the Wasatch, they are eighteen hundred feet thick. The Jurassic is almost entirely made up of soft clays, clayey calcareous marls, and intercallations of fine lithographic limestone. These rocks are therefore a lime and clay deposit.—Clarence King. The maximum development of the Triassic and Jurassic, east of the Wasatch, is not less than thirty-eight hundred feet.

Immediately above the Jurassic, on the eastern foothills, lies a "heavy bed of conglomerate, which is the base member of the Dakota Cretaceous. * * "The upper clay and sandstone beds directly under the bottom of the Dakota conglomerate have been called by Marsh the Atlantosaurus beds."—Clarence King. Hayden and Meek have shown that it is probable that the Jurassic beds extend eastward beneath the Cretaceous. As the Cretaceous extends in turn beneath the Tertiary, it is possible that there may be Jurassic beds in western Nebraska that cannot be observed, owing to the thickness of the overlying deposits of later geological periods. This is the more probable, since during Jurassic times there was a deepening of what had been the old Triassic seas, and a

*King's Report on the Fortieth Parallel.

deposition, as we have seen, of clay and calcareous marls and fine limestones, where previously sand and other shallow water deposits were taking place. At least in the Jurassic, water communication existed directly with the ocean, as is indicated by the abundant marine life that is preserved in these deposits.

Now, the length of these periods must have been exceedingly great, during which 3,800 feet of sediment was deposited, especially as a large part of them were of a character that never, so far as is now known, accumulate rapidly. The Jurassic beds at least, which are made up almost exclusively of soft clays, clayey calcareous marls and intercallated beds of thin lithographic limestone, must have been deposited with extreme slowness. Some authorities estimate the increase of sediment at a foot to the century, and others at only a few inches. Even at the larger figures, a foot to the century, the time involved would be 180,000 years for the Jurassic alone. Elsewhere, especially in Europe, the deposits of the Jurassic are thicker even than this, and therefore the probabilities are that this estimate is far too low. The preceding Triassic period was only one-fourth shorter than the Jurassic. This would give for the two periods combined 315,000 years. (See Dana's Manual, page 491.) During all these long centuries, therefore, and far into the Cretaceous, as we shall presently see, the greater part, and perhaps the whole of Nebraska existed as an extended land surface. The events that occurred here during these periods can never be certainly known. The imagination alone can, with the few data from the vegetable and animal life of the time, fill out imperfectly this lost page in our geological history.

Vegetable Life.—Nebraska during these periods, owing to its position, and because bounded on the west and southwest by seas of great extent, had a warm, temperate and moist climate. The peculiar vegetable forms of the Mediæval world must then have flourished here. Among these, in the Triassic period, were huge tree ferns, cycads and conifers, these last being principally araucarians, a family which is now mainly confined to South America and Australia. In the succeeding Jurassic, the vegetation was similar, and the conditions on the whole still more favorable for a gigantic growth. In this period were re-introduced the conditions favorable to the production and preservation of a vegetation for the formation of coal. To this period belong some of the coal fields of Scotland and England, of India and China. Either to this or the preceding

Triassic belong, also, the coal fields of Eastern Virginia and North Carolina. It is probable that while the conditions under which coal was accumulated in all geological times were similar, the plants differed exceedingly. The higher cryptogams obtained in carboniferous times, but in the Triassic Ferns, and especially conifers and cycads, were the common forms. (Le Conte). The Jurassic was eminently the age of naked seeded trees (*gymnosperms*), especially of the Cycads, which at that time culminated in the number of species and individuals. In fact, three-fourths of all the fossil Zamiæ and one-half the cycads known from all the geological formations, are from the Jurassic. No one can look at a cycad, with its long, fern-like leaves, without admiring its beauty. These vegetable forms are now confined to low, moist latitudes, but for immense periods of geological time they were the dominant type on what are now the plains of Nebraska. Here, in those times, along with tree ferns and araucarians, they made immense thickets and forests.

Animal Life.—The Mesozoic was eminently a Reptilian Age. All kinds of vertebrate life took on more or less of this type. Nebraska, being then a land surface throughout the Triassic and Jurassic periods, we will omit the consideration of the animal life peculiar to the seas. The land, however, with the peculiar vegetation referred to in the preceding section, and with its warm, temperate climate, was eminently adapted to the support of a land reptile fauna. What this fauna was, we can only imagine from the reptilian remains preserved in the deposits of these periods nearest to us. Many are found in western Kansas and eastern Colorado. The foothills are of Jurassic age, and are composed of clay and sandstone beds, overlaid directly by a heavy bed of the peculiar conglomerate of the Cretaceous Dakota Group. These beds, as already remarked, have been called Atlantosaurus beds by Marsh, from the prevalence in them of huge remains of Dinosaurs. No land animals of such gigantic size have ever been discovered elsewhere in deposits of any geological age. The most important locality for these remains is at Morrison and Canyon City, where the *Atlantosaurus immanis* (monstrous sized lizard) was found. Its femur was eight feet four inches long, which would indicate, on the principles of comparative anatomy, an animal walking on all fours of over one hundred feet in length and over thirty feet in height. It approximated closely in size to the limits beyond which locomo-

tion would be impossible, owing to the specific gravity becoming too great to be moved by muscular power. Apparently, to overcome this obstacle, its bones were made partially hollow, similar to those of birds. Atlantosaurus montanus was almost as large as the preceding. Eleven additional reptile forms were found in these localities, some of which were also of gigantic mould. One of them, however, *Creosaurus atrax*, was a small carniverous Dinosaur. It is also curious that among these gigantic forms there were two of the smallest Dinosaurs yet discovered. One of them was not larger than a cat. Another reptile found here is the type of a new group, and is named by Marsh *Stagosaurus armatus*. A crocodile found here had biconcave vertebræ like a fish. A small animal, structured like a possum (*marsupial*), was also found among these remains.

As observed already, some of these remains are the most gigantic land animals yet discovered. No land vertebrates approaching them in size have ever been discovered anywhere else. They probably represent but a tithe of the fauna of that period. As the general slope of the continent at that time was westward, and many great rivers must have flowed from the direction of Nebraska into the old Jurassic sea, it is almost absolutely certain that these gigantic land animals were carried there from the east, and that they represent the fauna of this territoty during the Jurassic period. If, therefore, we picture to ourselves the climate of that time, its curious forests of tree ferns, conifers, zamias and cycads, full of all sizes of reptilian life, and especially of the gigantic forms, along with a few lonely mamalian species, and some reptilian birds, it will give a faint idea of what Nebraska and much of the adjoining State of Kansas was during the Triassic and Jurassic periods.

Close of the Jurassic Period.—The Jurassic period was brought to a close by a further contraction of the cooling globe. One of the results of this contraction was, according to Whitney, the uprising of the Sierras. The rocks of the next period (Cretaceous) lie unconformably on or against its side. At the same time, the Wasatch, almost parallel with the Sierras, and the Uintas, almost at right angles with the last, also came up from the bottom of the old Jurassic sea. This probably raised the whole of this portion of the continent to so high a level as to drain the whole of what had been the Jurassic sea, and constituted it a land surface until the middle Cretaceous period.

The Cretaceous Period.

As is well known, the name Cretaceous is taken from the Latin *Creta*, meaning chalk, which is exceedingly abundant in deposits of this age in Europe. This, the closing period of the Mesozoic or Reptilian Age, is well represented in the rocks of Nebraska. It is somewhat remarkable, however, that no equivalent of the European lower Cretaceous has yet been found in the West. The equivalent of the lower green sand of the English Cretaceous is therefore not present here. It is even questionable whether the upper green sand, or middle Cretaceous, is here represented. The following is probably the explanation of this fact. As has already been stated, the Sierras, Wasatch and Uinta uplifts probably raised with them the adjoining territories that had been covered by the old Jurassic seas. During the whole of the period represented by the lower green sand of the European Cretaceous, the entire Rocky Mountain region was dry land. Whether its utmost height was reached at the close of the Jurassic, or whether it continued rising far into the Cretaceous, is only a matter for conjecture. The weight of evidence is, however, at present in favor of the former view. In Europe the lower and middle Cretaceous were periods of subsidence, and therefore it is probable that this was the case here. This sinking extended over a large part of the Rocky Mountain region, and embraced the plains of Nebraska as far east at least as Fort Calhoun, on the Missouri, and north of that point to a considerable distance beyond it. From Fort Calhoun, the eastern line of subsidence extended in the opposite direction first southward and then southwestward, entering Kansas a little west of the Otoe reservation. At least this far east the lower member of our Cretaceous system is found. It may once have covered the whole of the State, as there are indications that it has been removed from the Carboniferous and Permian by denudation. What adds greatly to the probability of this view is the fact that small areas of Cretaceous rocks are marked by Prof. White, in his geological map of Iowa, in the latitude of 41° 30′ as far east as the southeast corner of Guthrie County. If that view is the correct one, then this Cretaceous subsidence extended much farther eastward.

Divisions of the Cretaceous.—Nowhere in this country is the Cretaceous so well represented as in the far west, and on the upper Missouri. The following is the detailed section prepared by Meek and Hayden. Having gone over much of this ground myself,

their divisions on the whole appear to me the best possible. I have changed the descriptions of Meek and Hayden slightly to make them correspond more particularly with the geology of Nebraska.

		Divisions.	Localities.
Upper Series.	Fox Hills Beds. Form'n No. 5.	Gray ferruginous and yellowish sandstone and arenaceous clays containing massive molluscan, and reptilian fossils. Maximum thickness, 500 feet.	Fox Hills, near Long Lake above Ft. Pierre and along Big Horn Mountains. Not in Nebraska.
	Fort Pierre Group. Formation No. 4.	Dark grey and bluish plastic clays, also containing massive fossils near the upper part, also reptilian remains. Maximum thickness, 700 feet. Middle nearly barren of fossils. Lower Zone contains many massive chambered shells. Dark bed of fine unctuous clay, containing carbonaceous matter, with veins and seams of gypsum, masses of sulphuret of iron, small scales, fishes, local, filling depressions in the bed below.	Sage Creek. Cheyenne and White River above the Bad Lands. Not in Nebraska. Fort Pierre out to Bad Lands, down the Missouri to Gr't Bend. Knox County on Niobrara and on upper Republican.

		Divisions.	Localities.
Lower Series.	Niobrara Group, Formation No 3.	Lead gray calcareous marl, weathering to a yellowish or whitish chalky appearance, containing many large scales of fishes and many *ostrea congesta* attached to fragments of Inoceramus. Passing down into yellowish and whitish limestone containing many Inoceramus problematicus, ostrea congesta, etc.	Bluffs along the Missouri below the Great Bend, greatly developed below the mouth of the Niobrara, and on to Dakota County along the Missouri. West of this line extends an underlying rock to Kansas. Most extensive group of cretaceous rocks in Nebraska. Maximum thickness 200 feet.
	Fort Benton Group, Formation No. 2.	Dark gray laminated clays, sometimes alternating near the upper part with seams and layers of soft gray and light colored limestone. Many chambered shells and other marine molluscan forms.	Fort Benton on the upper Missouri, and along the latter from ten miles above James River to the Big Sioux, Black Hills. Found in Nebraska beneath the Niobrara Group, but rarely the surface rock. Maximum thickness, 800 feet.
	Dakota Group, Form'n No. 1.	Yellowish, reddish, and occasionally white sandstone with occasional alternations of various colored clays and beds and seams of impure lignite. Also, silicified wood and casts of marine mollusks. Many remains of the higher types of dicotyledonous leaves from tree forms.	Back of Dakota and in surrounding country. Thence southwestward into Kansas and beyond. Maximum thickness, 400 feet.

These groups are readily separated and distinguished on the upper Missouri and through Nebraska, except along the Republican River. Had I first studied the Cretaceous on the Republican, Meek and Hayden's divisions would have appeared inapplicable as these groups there shade into each other. The geologist, however, who first studies the rocks of this period on the Missouri cannot well deny the validity of this grouping. Since the rocks of this period have been studied in the mountains by the United States Surveys, two of the chiefs, Clarence King and Dr. Hayden, have agreed on a slightly different division. They retain No 1, or the Dakota Group as the basal member of the series. The next three, however, namely, the Fort Benton, Niobrara, and Fort Pierre

Groups they now call the Colorado.* The Fox Hills Group, Dr. Hayden's No. 5 becomes then, with this division, No. 3.

THE DAKOTA GROUP.

This was so named by Hayden because of its great development southwest from Dakota City in Dakota County. Beginning from below, it consists in the main of a whitish clay from a few inches to four feet in thickness, then various thicknesses of conglomerate and concretionary sandstone averaging from one to ten feet; next yellowish coarse sandstone from fifteen feet and upwards; and next a red hard ferruginous sandstone containing impressions of plants, leaves, wood, etc., from thirty to seventy feet in thickness.

Extent of the Dakota Group Deposits. — The Dakota Group towards the west extends under the Fort Benton and Niobrara Groups and therefore its real breadth cannot be ascertained. I have traced it, however, from east to west over a breadth of from sixty to ninety miles. In the States of Iowa and Kansas Lesquereux estimates its breadth as slightly greater. Its eastern boundary is that of the Cretaceous and can be seen in the accompanying geological map of the State. It is mainly found in the following counties: Dakota, Wayne, Winnebago and Omaha reservation, Burt, Washington, Cuming, Stanton, Colfax, Dodge, Douglas, Sarpy, Saunders, Butler, Seward, Lancaster, Cass, Gage, Jefferson, Saline, and occasionally in the counties bordering on these. Southwesterly it has been traced to Texas. It crops out in numerous places as the basal member of the cretaceous series in the mountains. It covers a large part of northwestern Iowa, and extends towards the northern limits of Minnesota. There are evidences of its presence in British America. Prof. Heer has also described fossil leaves from Greenland, some of whose genera and species are identical with those from the Dakota Group, and therefore it is probable that it has been continuous, as Lesquereux remarks, from the Gulf of Mexico to Greenland and other Arctic lands, or over thirty-five degrees of latitude.

Origin of the Dakota Group.—We have already seen that during, at least the lower Cretaceous, Nebraska, with a large part of the Rocky Mountain region was an extended land surface in process of slow subsidence. By the time the middle Cretaceous began, this subsidence had reached so low a level as to admit the Gulf of

*Havden considers the Fort Pierre Group from its organic remains most closely allied to the Fox Hills.

Mexico, which spread over the area where the sediments of the Dakota Group are now found. There can be no question about the Dakota Group being a shallow sea and beach deposit. Just such materials are now being deposited in existing shallow seas. Examples can be seen along the North Sea, on the Belgian coast, and along the shores of Holland where there are extensive muddy flats composed of substances which if compacted would be similar in constitution to the Dakota sandstone. Small grains of sand are rolled up by the sea which are mingled with the mud deposits brought down by the rivers. The rivers bring down iron held in solution which is deposited in the presence of organic matter on the bottoms, often giving the grains of sand a coating, which subsequently became loosely compacted sand rock with a rusty, red, or brown color. "Marine animals, especially shells, are rare in deposits of this kind." "It is shunned by every kind of land animals, and it has therefore no other remains imbedded into its compound but saurians and rarely fishes. It has no remains of marine plants because these do not grow on the soft ground."—(Lesquereux.)

Prof. Marcou and Capellini regarded the Dakota Group as a fresh water deposit. If the considerations already adduced are correct it cannot possibly have such an origin. It can also be added that at Sioux City, and in the bluffs in Dakota County are found mingled with dicotyledonous leaves peculiar to this deposit such marine shells as Pharella Dakotensis, Axinea Siouxensis, and Cyprina arenacea. Prof. Meek has also identified not less than twelve additional marine species from this group in Kansas where the leaf impressions are characteristically abundant. Its very extent contradicts such an opinion. It is from sixty to one hundred miles broad and adjoining and overlapping the Carboniferous and Permian, it extends from Texas through Minnesota to, and probably through British America to Greenland. It is not conceivable that there should be a fresh water deposit of such extent. The homogenous character of its materials also contradicts this view. No American geologist, however, ever entertained this opinion.

Discussions in Regard to the Character and Age of the Dakota Group.—No group of remains have ever excited more, and few as much interest as that of the Dakota. When first studied in Kansas, it was regarded by Prof. Hawn and Swallow as of Triassic age. Afterwards it was pronounced Jurassic by Prof. Marcou. "In the mean time Dr. Hayden sent some sketches of the leaf im-

pressions to Prof. O. Heer, of Switzerland, who complicated the discussion still more by pronouncing them to be of Tertiary age." Hayden himself had reported on the peculiar character of this group as early as 1853. In 1856 and 1857, assisted now by Meek, he resumed the study of this deposit in Kansas as they had previously done in Nebraska, and both reaffirmed the conviction which Hayden had previously expressed, that these rocks were of Cretaceous age. Dr. Newberry expressed the same conviction when their whole collection of leaves was submitted to him. This reference of these leaves to the Cretaceous, first by Hayden, and then by Meek and Newberry, produced a difference of opinion and much discussion among some European and American geologists. Dr. Newberry has given the details of this discussion in his "Extinct Floras." To settle the question of the geological age of the Dakota Group, Professors Capellini, of Paris, and Marcou, of Dresden, visited Nebraska and examined the stratiography of this group and collected the fossil leaf impressions which it contains, all of which were afterwards submitted to Prof. O. Heer for examination. In his report—*Phyllites du Nebraska*—seventeen new species were described with illustrations. In this report Prof. Heer admitted the accuracy of Hayden's original reference of this deposit to the Cretaceous. Capellini and Marcou also on stratiographical evidence came to the same conclusion, and admitted that they were much less successful than the American geologist, as they, unlike him were unable to discover the line of junction with the next group above. It therefore became settled in the minds of the eminent European and American geologists, who had especially investigated the matter, that the Dakota Group was the basal member of the Cretaceous in this region, and was the equivalent of the middle or lower part of the upper of the European Cretaceous. I have given this outline because, even yet, in the minds of some geologists who have not studied the history of these investigations there is a doubt about the cretaceous reference of this group.* It should also be remembered to the credit of Dr. Hayden that he was the first to outline, to name, and to ascertain the true position of this group.

Fossil Leaves of the Dakota Group.—As early as 1853 Dr. Hayden had obtained impressions of dicotyledonous leaves from the rocks, which he subsequently named the Dakota Group. They were remarkable for their modern aspect, as most of the genera

*See on this subject Lesquereux's Dakota Group Cretaceous Flora.

to which they belonged are still represented in our existing flora. The collection of these leaves has steadily gone on until the present time, some of the most important being made by Meek and Hayden in 1856 and 1857, and again in 1865. Prof. Newberry also engaged in this work in another field. Prof. Marcou and Capellini also added to the number, as well as Prof. James Hall, Lesquereux and Prof. Mudge. One of the first published reports, with drawings of the leaves, was that of Prof. O. Heer, of Switzerland. In 1874 the Hayden surveys published Lesquereux' Dakota Group, Cretaceous Flora, which combined all the previously published descriptions, with a great deal of original matter, and gave a full description of all these leaf impressions that had been discovered up to that time. According to this report there have been found thus far in this group 132 species, distributed among seventy-two genera. Of these there were of non-flowering plants seven species, and six of these were ferns. Of naked seeded plants (*Gymnosperms*) there were seven species, one of which was a zamia and six coniferæ. Two of these belonged to the giant cedar family (*Sequoia*), and one a glyptostrobus, similar to the one still growing in China and Japan. There were three moncotyledons, one of which was a palm. The dicotyledonous trees, called also exogens (*outside growers*), to which division all our common trees belong, were the most fully represented, all the remaining forms belonging to these classes. Among these there were five species of populus, the genus to which our cottonwood belongs. Closely allied to the last were four species of populites. Of the willows (*Salix*), there were six species. The oaks (*Quercus*), were represented by eight species, and the beeches (*Fagus*), by two. There were six species of buttonwood (*Platanus*), and one fig tree. There were two species of spicewood (*Laurus*), seven of sassafras and two of cinnamonum. The magnolias were abundant, as the presence of fine species attest. The tulip trees (*Liriodendron*), which are among the most magnificent of all modern trees, were represented by three species. One buckthorn (*Rhamnus*), one walnut (*Juglans*), and one sumac (*Rhus*), have left their remains in this group. Even an apple (*Pyrus*), and a plum (*Prunus*), flourished in those times.

No one, however, can get a clear idea of the character of this rich modern flora without studying its remains, or the remarkable and beautiful report of Lesquereux on "The Fossil Flora of the Da-

kota Cretaceous Group." I have also added these fossils to the cabinet of the State University, where they can be seen.

Origin of the Flora of the Dakota Group.—No geological question is more involved in doubt than the source or origin of the flora of the Dakota Group. So far as known it is entirely disconnected from all antecedent types. "The remarkable disproportion between the number of genera compared to species in the Dakota Group seems at first to corroborate the system so generally admitted now of a successive development of vegetable forms, according to a supposed rule of progression of more complex forms constantly originating by the multiplication or subdivision of simple organs of inferior types."—(Lesquereux). According to this view, as we go back in time there should be few species and more genera, and what species there are should differ only slightly from the characters assigned to the genera. There are, however, some genera in this group represented by from six to eight species, and it is equally probable that the others, if all the forms had been preserved, would have been fully as abundant.

It is, however, not scientific to depend on suppositions on either side. The facts alone should be considered. And the facts, so far as is now known, as already remarked, totally disconnect this flora from all that went before it.

We have already seen that the Dakota Group rests directly on the Upper Carboniferous or Lower Permian. The Upper Permian, the Triassic, Jurassic, and Lower Cretaceous are all wanting. The uppermost vegetable remains in the Permian, a calamite in the Rocky Mountains, is yet palæozoic in type. Even if we look at the vegetable remains in the Triassic of South Carolina and Virginia, nothing is found but forms representing ferns, equisetaceæ, cycads and conifers. Even in Europe the Triassic and Jurassic floras belong to the same types. No dicotyledonous leaf has been found anywhere before the Cretaceous. Now the slightest examination of the flora of the Dakota Group shows the "prodigious difference which separates this flora from that of any former epoch, even considering the antecedent vegetation of the Jurassic, known as it is from European specimens and publications." It differs equally from anything yet found in the Jurassic in America. "The ferns, conifers and cycads with a few equisetae, which constitute the whole known flora of that epoch are all of peculiar types, without relations to any of the species of the same families recognized as yet in the flora of the American Cretaceous."—(Lesquereux).

There are only two ways in which we can account for the sudden appearance of this Dakota Group flora. One is, that it appeared without any connection with antecedent types. It involves the theory that by some fiat of Nature's God it was spontaneously and suddenly produced. Few naturalists now accept this view. They regard the vegetable world as a connected chain. They are therefore in this case driven to use the "scientific imagination" and suggest the following explanation—the second explanation already referred to.

We have already seen that throughout the unnumbered centuries of the latter Permian, Triassic, Jurassic, and Lower Cretaceous Nebraska was an extended land surface, and covered by a colossal vegetation of which no memorials have been preserved. The peculiar animal life of the time flourished here as elsewhere. Now, it is conceivable that during these long periods, whose length is simply incalculable, vegetable life underwent many changes, because the conditions of climate and environment changed many times. The transformation therefore from primitive types was gradual, all the intermediate links of which have been lost, and the last factor, the flora of the Dakota Group alone preserved.

Climate of the Dakota Group Epoch.—Many of the genera of plants of the Dakota Group period are still flourishing in Nebraska, Kansas, and even in Minnesota. Professor Heer has also published a memoir on a group of Cretaceous plants from Greenland, whose facies resembles that of the Dakota Group. If the Greenland fossil Cretaceous flora is cotemporaneous with that of the Dakota Group, which seems probable, then a similar climate prevailed from southern Kansas to near the Arctic circle. However that may be, little difference can be detected between the fossil vegetable forms in Kansas and Minnesota, and therefore a temperate climate must have prevailed over this entire region, during Dakota group times, not greatly different from the one that now exists in Nebraska. The similarity of the vegetable forms that then existed, to those that now obtain here, proves that the climate of that epoch was much like ours to-day. It was, judging from the presence of some species, only slightly warmer than our present climate. It was colder, however, than the preceding Triassic and Jurassic, and also colder than the climate that subsequently prevailed in the Niobrara Cretaceous, and during Eocene and Miocene times.

The Fort Benton Group.

The preceding period was closed by the changed conditions brought on by a further subsidence of the region where its deposit are found. Where shallow seas and extended sea beaches and flats full of low islands had obtained, now rolled deeper waters and quieter seas. The deposits formed during these times have been called by Hayden the Fort Benton Group. They are dark gray laminated clays, sometimes alternating near the upper part with seams and layers of soft gray and light colored limestone, filled in many places with marine shells. Occasionally in Nebraska this group contains seams of impure lignite and other carbonaceous matter. It lies conformably on the Dakota Group below. It is so friable and easily eroded and disintegrated, that wherever it is left exposed, so far as I have observed, it has disappeared. In many places, however, where deep sections have been made by canyons and railroad cuts through the Niobrara Group, which lies above, its deposits are almost invariable present, and often in notable thickness. One of the finest of these exposures is seen below the mouth of Iowa Creek, in Dixon County, along the Missouri bluffs. Here for a long distance the line of demarkation between the Dakota, Fort Benton and Niobrara groups are distinctly seen and clearly outlined. Below Milford, on the banks of the Blue, and at other points in Seward County, in deep sections, it is also observed.

That this period was a long one is evident from the fact, as observed by Hayden, that its deposits are in some places 800 feet thick. The materials, too, are of a kind that are slowly deposited. It is probable that the numerous low islands that had existed in Nebraska during the previous epoch, had now mostly disappeared beneath the constantly deepening seas. Some land surfaces still existed in southeastern Nebraska, but no such memorials of its condition have come down to us as marked the preceding epoch. Marine life, however, was abundant. Meek alone has described from this group five species of Inoceramus, a mollusk distantly related to the oyster, and nine species of chambered shells, some of which were of great size and beauty. He has also given eleven additional marine molluscan forms*. The seas swarmed with fishes. Reptilian life was abundant, but this feature will be presented in the discussions of the next epoch.

*See Meek's "Cretaceous Invertebrate Fossils"

THE NIOBRARA GROUP EPOCH.

A still further subsidence of the continent, especially towards the north and west, inaugurated the Niobrara Group Epoch. Hayden gave it this name because of the great development of its deposits below the mouth of the Niobrara in northeastern Nebraska. Here its deposits consist of an impure chalk rock, varying from a grayish white to a pink bluish and yellow hue. Below the mouth of the Niobrara many of the chalk bluffs are several hundred feet high, with a perpendicular face often excavated beneath by atmospheric agencies. These chalk rocks are seen through Knox, Cedar, in many places in Dixon County, and in places on the lower Republican. Elsewhere the deposits, especially those beneath the stratum of chalk, are mostly of an impure limestone, which often shade imperceptibly into a silicate of lime. This stratum is often called the Inoceramus bed, from the immense numbers of this mollusk which frequently compose it. Under the Inoceramus bed there is in many places toward the southwest, a stratum varying from a few inches to fifteen feet in thickness, of an impure, yellowish, silicious limestone. According to Prof. Mudge, it is the characteristic feature of this group in Kansas. It can be observed at Milford, in Seward County, in places in Harlan County, and at many other points between these stations. Lately a chalk bed of this deposit was found near Red Cloud, in the Republican Valley. It is pure white, soft, easily worked, and contains little besides carbonate of lime and a small amount of iron carbonate, but not sufficient to color it. Judging from microscopic and chemical tests, it is as pure as the best European chalks.

The Niobrara is the most widely extended of all the Cretaceous groups in Nebraska. In southern Nebraska, from the western line of the Dakota Group to Harlan County—where it is overlaid by the Pliocene, it is over 100 miles wide. In north Nebraska, from Dakota County—where it begins to overlie the Dakota Group, it extends westward for over 150 miles. In general, the area on the geological map marked Cretaceous is all Niobrara Group, except a border from sixty to one hundred miles wide on the eastern rim, from the Omaha Reservation southward, which mainly belongs to the Dakota Group. As before intimated, it was mostly a period when deep seas overspread a large part of the area now covered by its deposits. Southeastern Nebraska was also a land surface during

this epoch. The eastern border, at least, of the Cretaceous area, was the eastern shore line of the interior sea of the time.

Vegetable Life of the Niobrara Group Epoch.—The diatoms and desnuds which abounded in some strata in the European chalk, were sparingly represented in the Niobrara Group seas. I have only in a single instance found a few diatoms under the microscope in some chalk obtained below the mouth of the Niobrara River. The specimen was overlaid by a portion of the skeleton of a fish which seems to have protected the silicious matter which had accumulated and which contained the diatoms.

The peculiar impressions of geologically modern leaves (*dicotyledonous*) which characterize the Dakota Group, are wanting in the Niobrara. Different seas now prevailed, and as is evident from the fossil animals, to be noticed hereafter, a warmer climate. Only one leaf impression, to my knowledge, has been obtained from this group in Nebraska. It was found in the Inoceramus bed in Dakota County, by Hon. Jesse Warner, and presented to me for the cabinet of the State University. Owing to the absence of nerve marks, it could not be certainly identified, but its external form was that of a laurus.

Fossil wood, however, is abundant, both petrified and agatised. Of this material I have made microscopic sections of seventy-nine specimens, which under the microscope showed the structure of the original wood. Of these seventy-nine specimens, forty-seven belonged to the conifers of araucarian type, and the balance were cycads and zamias. Judging only from these few remains, the dicotyledonous vegetation that characterized this region in Dakota Group times, had retreated, where to is not certainly known, but probably northward or northeastward. A southern flora, or one that had reached its culmination in Jurassic times, returned again to this region by migration. At the same time a few species from the Dakota Group era lingered among these mediæval vegetable forms.

Animal Life of the Niobrara Group Epoch.—The chalk of Europe was largely made up of remains of rhizopods which were so abundant that a cubic inch, according to Ehrenberg, contained millions of these low organisms. In our own chalk seas they were probably little less abundant, though not so well preserved. Some specimens of chalk that I obtained below the mouth of the Niobrara, and in Cedar County, afforded them, under the compound microscope, in

immense numbers. Often, however, no trace of these organisms is left. I found them where they had apparently been preserved from crushing first beneath the huge scale of a fish, and then in the hollows of reptilian vertebra. As in the European chalk, the spicula of sponges are occasionally found in this group.

This era was evidently well adapted to the support of molluscan life, though the number of species is less than from the preceding and the next two following. The number of individuals, however, is enormous. One of the last tasks that the lamented Meek performed, was the completion of his great work on the Invertebrate Palæontology of the Cretaceous, in which he described four species of mollusks from this group. One of these was a species of oyster (*Ostrea congesta*), which must have been very abundant, as remains of it are found in every stratum of this group. An anomia is found principally in Knox County. An oyster-like shell (*Inoceramus problematicus*), and a variety of the same, are the most abundant, some whole strata being almost entirely composed of it. The Inoceramus bed is so named from the abundance of this shell. Related to these is a genus represented by two species which were remarkable for their size. They were described by Conrad, and named *Haploscapha grandis* and *H. eccentrica*. The former is of gigantic size, being twenty-seven inches in diameter, and the latter nine inches. They are found in this group on the Republican, Solomon and the Smoky Hill. In the stratum of yellowish impure limestone beneath the Inoceramus bed there are many impressions of ammonites and nautilus and other chambered shells. They are, however, so poorly preserved that it is impossible to identify them with any certainty. One impression of an ammonite from the chalk in the cabinet of the University is eighteen inches across.

The seas of this era swarmed with fishes. In the chalk in Knox and Cedar counties, for over a hundred feet through it vertically, almost every spadeful of rock contains fish scales or teeth or both. Many of the species were of reptilian type, or at least were predaceous and allied to the modern saury or salmon. Cope has described forty-eight species, most of which were from the Niobrara Group in Kansas. Many of these I have identified from the same group in Nebraska. One of the most abundant of these fishes, and also one of the most rapacious that ever existed, is known as *Portheus molossus*.—Cope. Its bones are sometimes found to project from the sides of the limestone bluffs in the Republican Valley.

"The head was a few inches longer than that of a grizzly bear, and the jaws even deeper in proportion to the length. The muzzle was shorter and deeper than that of a bull-dog. The teeth were long cylindrical fangs, smooth, glistening, and of irregular size. At certain points in each jaw they projected three inches above the gum, and were sunk one inch into deep pits, being thus as long as the fangs of a tiger, but much more slender. Two pairs of such fangs crossed each other on each side of the end of the snout." Six species of these rapacious fishes have left their remains in these rock, and probably more will be found with the progress of discovery.

In this group in Nebraska, the remains of sharks are quite abundant. Many fine specimens of their teeth have been obtained in the Inoceramus bed at Pleasant Hill in Saline County, from near Seward, Milford, and in Dakota County. Some of these teeth represent the pavement teeth kind (*Cestraciont—Pycodus Mortoni*), and others the common modern shark family.

Reptiles.—Many reptilian forms from the west have been described by Leidy, Marsh and Cope. The latter, from the Niobrara Group of Kansas, alone, has described thirty-seven species of reptiles. Many of these I have identified from the same group in Nebraska, and as this group is continuous through these two States, it is almost absolutely certain that they all, or their equivalents, swarmed here during those times. What adds to this probability is the certainty that there were deeper seas towards the northern boundary of the Niobrara Group waters. "In the deep seas of this era could have been seen an animal lying on the water, with a body of elephantine size. Its neck was twenty-two feet long, snake-like, and with an arrow-shaped head. One minute it would run this long neck in the water, and then, raising it up, would peer for victims over the deep. Its tail was also of serpent pattern, and served to balance it behind, or propel it through the water, though it also had two pairs of paddle-like limbs, resembling those of the Plesiosaurus, from which it differed mainly in the arrangement of the bones of the breast. This is the *Elasmosaurus platyurus*, (Cope), a carniverous sea reptile adapted to deep water. Its total length was fifty feet. It was structured to swim below or on the surface, and while lying still would explore the depth forty feet below without changing the posture of its body. That it fed on fishes, is evident from the scales and teeth found in the posibon of its stomach."

—Cope. A few years ago a magnificent specimen of what I take to be this reptile, judging from a photograph submitted to me, was found in Dixon County, at the edge of the Missouri bluffs. Unfortunately, it fell into the hands of men who cared more for money than for science. They attempted to make money by exhibiting it, and after this proved a failure, gave it away partly by piece meal.

A species similar to the last, and also described by Cope, was the *polycotylus latipinnis*. It was extraordinary for the length of its neck and attenuated head, though its tail was short and massive, doubtless to balance its long neck while moving through the water and capturing its prey. It was a powerful swimmer, as is evident from its two pairs of paddles, four feet long, with a lateral expanse of from eleven to twelve feet. The bones of a reptile found near Sheridan, Kansas, has been referred to the genus Plesiosaurus, of which there have been found and described the remains of many species in the European chalk. The two preceding and this last (*Plesiosaurus gulo*) are the only ones in this large family of *Sauroptergia* that have yet been found in the Cretáceous in the West. This is evidently, as Cope has remarked, because of the presence of another order, almost entirely absent in Europe, but the real rulers of our Cretaceous seas—the Pythonomorphs or Mososaurs of Leidy- These reptiles had characters that related them to the lizards and serpents, and in the absence of a sternum, to tortoises and plesiosaurs. They pre-eminently characterized the cretaceous seas of America, being found in the deposits of this age in Alabama, New Jersey, and especially in Kansas and Nebraska. One-half of all the reptiles found here belong to this order, but only four species have yet been found in Europe.

It was Cope who first made known the wonderful forms of these reptiles, especially the mouth parts. Their form was very much elongated, especially the tail. The head was long, conical and flat, with the eyes directed upward and forward. As in snakes, the roof of their mouth was furnished with four rows of conical large teeth, which were not structured for masticating, but for seizing their prey. The structure of their jaws was unique among animals. Though they swallowed their prey whole, like snakes, they were without their expansability of throat, which is due to an arrangement of muscular levers "supporting the lower jaw." They were, however, furnished with an additional joint in each side of this organ,

nearly midway between the base and the anterior end. This joint was of the ball and socket type, which enabled it to make an angle outward, and thus greatly to widen the space between the two halves. This arrangement, in fact, seems to have anticipated that of the arms, which can be made to imitate it by placing the hands close together, extended forward and with the elbows bowed out. The ends of the bones, like in the serpents, were only bound together by flexible ligaments. This posture of the arms gives a diamond shaped space, and represents the expansion practiced in these reptiles to enable the passage of a large fish or other victim. The arms only represent the size of the jaws of the smaller species, the larger ones being much more extended. The basal half of the jaw, like in all other reptiles, is attached by a column-like bone (quadrate bone), whose shape and form varies a great deal in the different species, being dependent on the degree of twist to be allowed or needed. In consequence of this peculiar structure, the mouth of the gullet must have been prolonged forward, and the throat must also have been loose and baggy like that of a pelican. Such a structure would also necessitate the throwing forward the opening of the wind pipe or glottis, as this is always in front of the gullet. The tongue must also have been far forward, long and forked. The only noise that could have been made by such an animal would be a hiss like in the serpents, but a hiss which for loudness would resemble distant thunder. They were furnished with two pairs of huge paddles "which were attached to the body by short peduncles." Their tails were flattened, but their strokes, aided by the paddles, must have sent them through the water with great velocity.

The most gigantic of these reptiles (*Liodon proriger*, Cope), attained a length of not less than seventy-five feet, and probably much greater. This species was very abundant. It had a long, projecting muzzle, remotely resembling that of the Atlantic blunt-nosed sturgeon, but the ends of the lower jaw were much more blunt and massive. Such an arrangement must have made it a terrible ram, and no doubt it often stunned its victims by a butt before swallowing them. *Liodon dyspelar*, Cope, was perhaps equally as large as the preceding, but by no means so abundant. Two somewhat smaller species of *Liodon* occupied the same seas.

A genus closely related to the last, and whose remains are specially abundant in Nebraska, is *Clidastes*. The species of this

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genus were more flexible, and much more elegant in form than the Liodons, and also less in size. "Perhaps to prevent their distortions from dislocating the vertebral column, they had an additional pair of articulations at each end." (Cope.) One of these species *Clidastes tortor*, (Cope), was only thirty feet long, but its narrow pointed head had a length of thirty inches. Its teeth had cutting edges lengthwise of the animal, and in the lower jaw were eighteen in number. "The palate was armed with eleven teeth." The light and slender bones and elongated vertebrae indicated that this reptile was of exceptionally slender proportions. The largest species (*Clidastes cineriarum*), was about forty feet in length. Another species, remarkable for its elegance and lance-shaped head, was described by Marsh, and named by him *Clidastes pumilus*. It was only about twelve feet in length. Altogether, Marsh has described from the Niobrara Cretaceous five species, Cope three, and Leidy one species.

Closely related to the preceding genus is that of Platecarpus. Of the species assigned to this genus, seven were described by Cope and four by Marsh. These reptiles were almost equally abundant with those in the preceding genera in the old Niobrara Cretaceous seas.

Tortoises have long been known from the Cretaceous of the Atlantic coast, but have only lately been described from the Niobrara group. Three genera and as many species are now known. The largest (*Protostega gigas*, Cope), had a spread of expanded flippers of over fifteen feet. The ribs in this species did not entirely coalesce, and in its entire structure it was like an ordinary turtle just hatched.

European writers describe an immense number of flying reptiles (*Pterosaurs*), from the chalk. Prof. Owen and Von Meyer first made known their true structure, since which time they have excited much interest among geologists. All sizes, from minute forms to those with an expanse of twenty-five feet of wing, have been found in the European chalk. Those that I found in Nebraska were so fragile that they fell to pieces in excavating them. Prof. Marsh has described one from the Niobrara of Kansas, with a spread of wing of eighteen feet, and one (*Pterodactylus ingens*), with a spread of twenty-three to twenty-five feet. The one that Cope has described, from the same region, (*P. umbrosus*), was still larger, having, as he claims, a spread of twenty-five feet. Marsh

has shown that the American pterosaurs were toothless, differing in that respect from the European, and for this reason erects them into a new order, called Pteronodontia, which means winged toothless. One of these flying saurians, "(*P. ingens*), has toothless jaws four feet long." Unquestionably there were many more species, some gigantic, and some, as in Europe, small. They roamed through the air, often plunging down to seize fish or reptile, they would fly away to some rock on a neighboring coast or island and there consume their victims at leisure.

No crocodiles have yet been described from the Niobrara group, but they were undoubtedly present in that old sea, as they existed in the preceding and subsequent eras. One (*Hyposaurus Webbii*, Cope), obtained in the Fort Benton group of lead colored shales, was about ten feet long, and belonged to the division that had subbiconcave vertebra, and with a long subcylindric snout.

Only one species of Dinosaurs has been found in the Niobrara group. They were no doubt abundant in this era, but the conditions for their preservation were not favorable. Many have been found in the geological equivalent of the Niobrara in New Jersey. They were present in considerable numbers during subsequent Cretaceous eras, and no doubt on the land surfaces of the time they were the rulers.

Birds.—Nothing is more remarkable about this marvelous age than the peculiarities of its bird life. Like all other vertebrate forms, it was almost entirely of reptilian type. Thus far eleven species have been described from the Niobrara group deposits. The New Jersey green sand has yielded five more. The Saururæ were the most remarkable, as they combined fish, reptile and bird characters. They are embraced in two genera, *Ichthyornis* and *Apatornis*. They had no horny beak, like modern birds, but in lieu of it they had slender, thin and long jaws, filled with sharp conical teeth in sockets, numbering at least twenty on each side below, and Marsh thinks as many above, though that could not be ascertained from the specimens. "Their vertebræ were amphicœlous or biconcave, as in fishes and many extinct reptiles, but in no modern bird." —Marsh. Of the former there were two species, namely, *Ichthyornis dispar* and *I. celer*. The generic name (*Ichthyornis*), means fish-bird, referring to the fish-like structure of its vertebræ. They had a keel on the breast, like modern birds, for the attachment of the muscles of flight. Marsh supposes that the tail, which was not

found, was vertebrated like the old Jurassic birds, but probably shorter and less reptilian. In size they were not larger than pigeons, but were capable of flight.

Three others resembled the last in the possession of teeth, which, however, were placed in grooves in place of sockets. They had no keel, but on the other hand had ordinary bird vertebræ. Two of these, namely, *Hesperornis regalis* and *Lestornis crassipes*, were of gigantic size, the former being five and a half feet high, and the latter six feet. This combination of fish, reptile and bird characters is so unique that Marsh has erected out of them two new orders—*Odontotormæ* (socket-toothed), and *Odontolcæ* (teeth in grooves), and a new subclass—*Odontornithes* (toothed birds). It is remarkable that the presence of these toothed birds in the Niobrara group era —birds that had not yet been entirely separated from the fish and reptile classes—is exactly what the doctrine of evolution demands. Modern birds are the most specialized of all animals, but these old Cretaceous forms raise the doubt whether they are most reptile or most bird. They are a transition form between the two classes.

From these brief outlines, it is evident that there was a most vigorous life during the Niobrara group times. The oceans swarmed with many kinds of fishes, a large proportion of which were rapacious. Gigantic reptiles flourished on sea and land. Flying saurians navigated the air, many of them of huge size. Reptilian birds abounded, of all sizes, from diminutive forms to gigantic dimensions. During the earlier and middle portion of this era, the Niobrara ocean was connected on the west with the Pacific. Later, the sea bottoms were raised up along the Rocky Mountain chain, giving access and egress alone from the Gulf on the south, and the Arctic Ocean on the northwest. A slow process of elevation continued on the east as well as on the west, contracting this ocean to ever narrower limits. A reverse movement was now going on from what was taking place early in its history. Then it was in process of subsidence, now it was in process of slow elevation. When sand bars eventually were thrown across the channels of moving waters, much of its life was imprisoned and gradually destroyed. The most vigorous species and individuals would last the longest, but all eventually had to submit to the inexorable fate of final extinction.

CHAPTER III.

MEDIÆVAL OR MESOZOIC TIMES IN NEBRASKA, CONTINUED.

Fort Pierre Group Cretaceous.—Its Position and Extent.—Thickness.—Life of this Epoch.—The Fox Hills Group.—Its Exposures, Character and Extent.—Its Vegetable and Animal Life.—Laramie Group.—Where Exposed, and Probable Presence in Nebraska.—Conformability to the Preceding Groups.—Whence its Materials were Derived.—Its General Character and Thickness.—By Whom Explored.—Its Great Extent.—Its Characteristic Feature.—Character of its Flora, and the Great Number and Modern Character of its Species.—Animal Life, made up of Marine, Brackish and Fresh Water Species.—Reptilian Remains.—Transition Character of this Group.—Probable Existence of Coal in the Cretaceous Groups in Nebraska.—How this can be Ascertained.—Close of the Cretaceous and Transition Period.

Fort Pierre Group

THE preceding (Niobrara Group) era came to a close by a continuation of that process of elevation that eventually drained the region where its deposits now constitute the surface rocks. Here and there the deeper portions of the old sea beds were still filled with water It is doubtful, however, whether these Fort Pierre seas in Nebraska were at this time connected with the Ocean. However that may be, the filling up of these seas gave us the peculiar deposits of this era. It is possible that the elevation going on at the close of the preceding era continued until the whole State was a land surface. The great inequalities of the Niobrara group, on which this group was laid down, suggests this explanation. It is hard to conceive a sea bottom so uneven and irregular. If, however, it was first elevated into dry land, and exposed to sub-ærial action, which produces inequalities of surface, its broken character is accounted for.

Two regions of Nebraska contain these deposits. One of them is in northeastern Nebraska, in Knox County, below the mouth of and for a short distance along the Niobrara. The other is on the Upper Republican, towards the west line of the State.

The materials of the Fort Pierre group, in Nebraska, are made up largely on the Upper Republican, of occasionally thin beds of

brownish sandstone, underlaid by dark gray plastic clay, calcareous shales, sometimes containing sulphuret of iron, and more rarely carbonaceous matter. A large amount of gypsum is present, which often has the form of selenite. The star-like shapes which it frequently assumes, makes it desirable for cabinets. The masses of selenite scattered over these deposits, on the Missouri bluffs, beyond the Niobrara, has given them the name of shining hills. From the occasional presence of scales of fishes, and still more rarely of ammonites and other chambered shells, I conclude that only the lower member of this group is present in Nebraska.

On the Upper Republican this group in many places lies beneath the Tertiary, and can only be seen in cuts and canyons, and the sides of bluffs and ravines. It almost certainly extends from near the mouth of the Niobrara in a southwesterly direction across the State. Passing beneath the Tertiary, it is not seen again until the western Republican region is reached in Hitchcock and Dundy counties. It runs, therefore, proximately parallel to the Niobrara group, and on its northwestern side.

Clarence King unites this group with the preceding Niobrara and Fort Benton group, to constitute the Colorado group. Hayden and White, on the other hand, attach it to the next above, or Fox Hills group. King's reason for this reference is lithological. That is, in the character of its rocks and other deposits it is much like the preceding groups. Hayden and White refer it to the Fox Hills groups or palæontological grounds, its animal life being more nearly like that of the next era.

The Fort Pierre sea that extended diagonally across the State from the mouth of the Niobrara and beyond represents a depression left or made after the elevation of the Niobrara group area above the old oceans. As already intimated, it is questionable whether this interior sea of Nebraska was connected with the ocean, except for a very brief period. The rarity of organic remains in this territory in this group is indicative of that unfitness for life which characterizes a sea that is losing more water by evaporation than it gains. Gypsum, which is so abundant in this deposit, is also formed under the same circumstances. Hence the vegetable and animal life that it here at first possessed gradually but surely was exterminated.

Elsewhere, however, it was very different. While this region was steadily rising, further northward and westward it was for a time slowly sinking, and had direct communication with the ocean.

At Fort Pierre, on the Upper Missouri, this group constitutes the hills along the Missouri, and extends to the Bad Lands. From Fort Pierre it also extends northward to the Cheyenne and Moreau Rivers, where it dips beneath the Fox Hills group. It also occurs on the Yellowstone.—(Meek and Hayden.) As already observed, it extends from Fort Pierre to the Great Bend, below which, to below the mouth of the Niobrara, it rests on the uneven surface of the Niobrara group. This group is met with again on the eastern base of the Rocky Mountains and northward to and beyond the Black Hills. It is seen westward, along the line of the Union Pacific Railroad, on and beyond the Laramie Plains. Where the grayish black carbonaceous shales and marls, and the nearly black arenaceous clays prevail, and no superficial deposits cover them, they give a barren, bleak appearance to the country.—(Meek.)

The thickness of this group on the Upper Missouri is not less than 700 feet. There are a few localities where it is even greater. It was therefore a very long era; so long, indeed, that the ages of human history are as nothing compared with it. During all this time a large portion, and after the middle of the era the greater portion of what is now Nebraska was again an extended land surface.

Life of the Fort Pierre Group Epoch.—From the few vegetable remains in the form of petrified and agatized wood that has been preserved, it is evident that the vegetable kingdom was represented mainly by the forms that characterized the preceding era. These, it will be remembered, were mainly cycads, zamias, araucarian conifers and tree ferns.

The animal life of the seas was probably richer than in the preceding era in molluscan forms, and poorer in reptilian life. The Cretaceous, the last period of Mesozoic times, was drawing to a close, and with it its characteristic life.

Meek has described one echinoderm from this group. He has also described two species of oysters and several varieties. Closely related to the oysters were two Gryphæa and eleven species of Inoceramus. Some of these were of great size and beauty. *Inoceramus sagensis* was nearly six inches long. *I. vanuxemi* was still larger, being ten inches long and nine inches high. The bivalves seemed to have been specially abundant, as besides the preceding, Meek has described thirty-five species. Thirty species of univalves have also been described. There were many beautiful chambered shells. Two baculites were abundant. Among the eighteen ad-

ditional species of chambered shells there were seven of *Heteroceras* and one *Placenticeras:* This last was a form of exceptional beauty. P. Placenta was equally fine. The three partially uncoiled scaphites show the beginning of a return to the original form of chambered shells. The three species of Nautilus are as perfect as the finest from existing seas. Fish life was abundant. Reptiles were present, but not in such amazing numbers as in the preceding era. The commonest kind being species of *Mosassaurs.*

This era was closed by a further elevation of the country in Nebraska, on the Upper Missouri and wherever this group now constitutes the upper rock of a region.

The Fox Hills Group.

No deposits of this group are exposed in Nebraska, and it is uncertain whether any exist in the State. If they are present, they underlie the Tertiary in the northwestern part of the State. As this group constitutes the surface or upper rock in the Fox Hills, from which it was so named by Hayden, above Moreau River, on the upper Missouri, and near Long Lake, above Fort Pierre, it is possible that it also runs in a southwesterly direction, and underlies the Tertiary in northwestern Nebraska, as stated above. In doing so it would follow the law of the preceding groups in Nebraska, each of the newer following after the preceding on its northwestern side. This group is also found along the base of the Big Horn Mountains, on the North and South Platte Rivers, and at other points in the mountains. Its thickness is about five hundred feet.—(Meek and Hayden.) It is largely composed of gray ferruginous and yellowish sandstone and arenaceous clays. During the deposition of these deposits, the greater part of Nebraska was an extended land surface. Nebraska doubtless drained into this Fox Hills sea, but the sediments that filled it up were derived mainly from land surfaces on the west and north, as is indicated by their character. That it was also a long period, is evident from the thickness of the deposits—500 feet in the region of the upper Missouri. According to Clarence King, (Systematic Geology, p 349), east of the North Platte and north of the Union Pacific Railroad in Wyoming, its maximum thickness is 4,000 feet. At the most rapid rate of deposition, the time involved in laying down such a mass of sediment is beyond calculation. According to Hayden, Meek and Lesquereux and others, it was the closing portion of

Cretaceous and Mesozoic times in the West. Clarence King, Le Comte, Stevenson, Powell, Newberry and Cope, however, regard the next group above (Laramie Group of King and Hayden), as the closing member of the Cretaceous. It will, however, suit my present plan best to consider the Laramie (also called by Hayden Lignitic Group) as the transition group from the Cretaceous to the Tertiary.

The vegetable remains found in the Fox Hills group still indicate the presence of cycads, zamias, tree ferns and araucarian pines, but in greatly diminishing proportionate numbers. There is already a large admixture of more modern tree forms.

Animal life was specially rich in molluscan forms, closely related to that of the preceding group, or Fort Pierre fauna. Like the latter, it contains the remains of many chambered shells, such as baculites and scaphites, the latter being specially abundant and beautiful. No more beautiful shell ever existed than Scaphites Conradi, which is found in these deposits. Other unrivaled shells and bivalves were also abundant. Vertebrates were represented by numerous fishes and some large reptiles, the commonest being in the Fort Pierre group, Mosasaurus Missouriensis. No doubt the plains of Nebraska, during this epoch, was the home of huge Dinosaurs and reptilian birds, but their remains, under the geological circumstances of the times, could not be preserved to us.

Laramie Group.

This is the Lignitic group of Hayden, but changed to Laramie by mutual agreement between Dr. Hayden and Clarence King. Like the preceding, it is not exposed in Nebraska, but may be present in the northwestern part of the State, underlying the Tertiary. A line joining the Laramie on the Missouri and its eastern exposures in Colorado, would pass across northwestern Nebraska. As this group is known in numerous places to pass under the Miocene, its presence in northwestern Nebraska in the same position is not impossible. However that may be, it represents, even more than the preceding, a very long epoch, and the history of our plains, the greater part of which at least was, during its continuance, a land surface, can only be surmised by studying the character of this group, and the events which it represents.

It is the last of that series of groups, commencing with the Dakota, that are conformable through their united thickness of not less than 12,000 feet in the Rocky Mountain region. Of these 12,000 feet of sediment, four-fifths are of sandy materials, more or

less mixed with calcareous deposits, which were derived mainly from a land mass that was raised up at the close of the Carboniferous, and extended from the Wasatch west of the meridian of 117° 30′ for 200 miles westward, and for an unknown distance north and south.—(King.) The materials of this land mass were mainly silicious, and fully seven-tenths of the deposits that constitute these cretaceous rocks came from their disintegration and erosion. At the close of each epoch represented by these groups, the shore line of the old interior cretaceous ocean retreated farther to the west and northwest. By the time the Laramie epoch was reached, it was, during much of the time, only a vast marsh or bog, full, no doubt, of low islands, and subjected often to incursions from the sea, and again constituting an estuary, and occasionally even becoming a fresh water lake. All this is evident from its vegetable and animal remains, which sometimes are marine, sometimes land, and sometimes of brackish and fresh water types. From the Triassic to the Cretaceous, and through its groups to the upper boundary of the Fox Hills, only marine forms are found, except in a very few instances where a few fresh water species exist underlaid and overlaid by a true cretaceous fauna.

The materials of this Laramie Group are, like the preceding, principally sandstones, but varying a great deal more in lithographic character in different sections. Intercallated with the sandstones, at various horizons, are clayey and shaly layers, and a few beds of pure clay, and many strata of carbonaceous shales. The principal colors are buff, pink, red and various shades of yellow. Sometimes the dip is slightly east or west, or even entirely horizontal. Its undulations are wave like, and the inclination of the flanks are always under 5° or 6°.—(Clarence King.) The thickness of this series of beds ranges from 1,500 to 5,000 feet.

This group can be studied to great advantage at the exposures along the railroad east of Separation station, where colored sandstones, some clayey beds, and a number of coal seams, leaf impressions and carbonized stems are found, and often exposed. Nowhere, however, is it seen on a grander scale than in the Upper Missouri, where it was first noticed and reported on by Lewis and Clarke, as early as 1804. From a Mandan village on the Missouri, they traced these lignitic measures to the Yellowstone, and for a great distance along this river. The length of these measures, as observed by these explorers, was over six hundred miles. After-

wards, Audubon and Morris explored the same region, and gave details similar to those of Lewis and Clarke. No one, however, has done so much to make known the character and the great extent of this group as Dr. Hayden. Commencing his explorations in 1854, and continuing them down to the present time, he reduced to order the data which others as well as himself accumulated. Lesquereux, speaking of his work in this field, remarks: "His researches show the constant vigilance and circumspection of a master, attending to the performance of a great work, the building of a monument whose plan has been prepared by serious scientific studies." Hayden considers that the area of the Lignitic (Laramie) on the Upper Missouri cannot be less than 100,000 square miles, without taking into account the great belt that extends far north from the United States into British America.* Altogether, from British America to the Black Hills, the area covered is not less than 125,000 square miles. Between the Black Hills and the Rocky Mountains, there is still another area of 1,700 square miles. The extent of the southern basin, which commences south of Cheyenne and extends to the Colorado plains, east of Denver, and southward to New Mexico, has not yet been estimated.

The most characteristic feature of this group, as already indicated, is the great number of carbonaceous shales and true coal beds which it contains. Fifteen and twenty coal beds sometimes occur in the course of a thousand feet.—(King). Artesian borings at Rock Springs station in 700 feet brought to light seventeen coal seams, the principal bed being eleven feet thick. Some beds are known and worked that are over thirty feet in thickness. When the great extent of this coal field is considered, it becomes apparent that it is only second in importance to the coal fields of the Carboniferous Age. As is well known, the coal belongs to the series of lignites, and is a superior article.

Vegetable Life.—The vegetable kingdom had now become clearly modern, the Mesozoic features having passed away. The Flora of this group has been carefully studied by Lesquereux, who has described from this and the Green River Groups 329 species. This is probably only a fragment of the rich flora of that time, but it is enough to show its general character, and the kind of forests that must have obtained also over the land surface of Nebraska.† In

*Hayden's Annual Report for 1874, p. 20.

†See Lesquereux's Tertiary Flora, Vol. VII. of U. S. Geological Surveys of the Territortes, F. V. Hayden, Geologist.

his list of Flowerless plants (*Cryptogamiæ*), there are a few fungi, one lichen, eight algæ, one moss, four lycopods, twenty ferns, four colamites, etc.

The Flowering Plants (*Phænogamiæ*), were most fully developed. Among the naked seeded were one zamiæ and sixteen cone-bearing trees. These latter first appeared in the Devonian, and apparently culminated in the Tertiary, from which at least 200 species have been described. Among these in the Laramie Group were eight sequoias, the genus to which the giant trees of California belong. Five species of grasses have also been described. The Palms, "those noble children of the sun," were represented by at least three genera and fifteen species. One beech (*Fagus*), flourished at that time. No family, however, surpassed in the number of individuals the Oaks (*Quercus*), of which eighteen species have been described from this group. At the present time there are only thirty species known to the entire United States. Even the Chestnut (*Costanea*), was then already present. Four species of Willow (*Salix*) must have been, judging from their remains, abundant. Curious enough, the Cottonwood (*Populus*) was then represented by at least twelve species. The Sycamores (*Platinus*) have left the remains of five species in this group. Most wonderful of all is it that already twenty-three species of Fig tree (*Ficus*) have been described. Whether their food was equal to the fig of the present time, is uncertain, but if so, the monkeys that appeared in the Green River Eocene had fine living. Ash (*Fraximus*), Dogwoods (*Cornus*), and the Grape-vine (*Vitis*), were all at home in this group. That noble, majestic and beautiful named tree, the Magnolia, which is the pride of the south, flourished during these times, as the remains of four species attest. Eight species of the Maple family (*Acerineæ*), and nineteen of the Buckthorn (*Rhamneæ*), also abounded. That noble tree, the Black Walnut (*Juglans*), which had appeared first in the Dakota Group Cretaceous, had now increased to six species. Five species of Sumach (*Rhus*) were in company with the last. Even an Eucalyptus flourished at this time. Many other forms, to which my limits will not permit me even to allude, illustrate the wonderfully rich and divergent type of the Flora at that time—a Flora that combines many semi-tropical and high temperate characters.

Animal Life.—The Animal life of the Laramie Group has been regarded as unique and exceptional. Its marine forms are al-

most entirely Cretaceous, while its lacustrine species are most closely allied to the Tertiary. Oysters (*Ostrea*) are the most abundant in species and individuals of all the marine forms.

The following marine mollusks of Cretaceous type are reported from this group; the first three being given by King, and the remainder by Meek.*

Avicula Nebrascana.
Nucula cancellata.
Ammonites lobatus.
Ostrea glabra.
Ostrea subtrigonalis.

The following brackish water species are also given from this group, by Meek:

Cyrena, one species.
Carbicula, five species.
Carbula, three species.
Certhida, one species.
Hydrobia, five species.
Micropyrgus, one species.

The following are the fresh water species:

Unios, four species.
Sphærium, five species.
Limnæa, one species.
Planorbis, four species.
Bullimus, three species.
Goniobasis, nine species.
Viviparus, eight species.
Campeloma, three species.
Valvata, three species.

There are some others inhabiting both brackish and fresh water. A few land shells of the genera, Helix and Hyalina are also found mingled with the above.

The most remarkable, however, of all the facts connected with the animal remains of this group, is the presence of reptilian remains of Cretaceous type. At Black Buttes station, about half-way up the base of the bluff, are laminated light gray shales over a coal

*See Meek's Invertebrate Palæontology of the Cretaceous and Tertiary Fossils of the Upper Missouri, Vol. IX. of U. S. Geological Surveys, F. V. Hayden, Geologist.

bed two feet thick. Here are found marine and fresh water shells. About 100 feet from the top, in a dark gray sandstone filled with leaves and stems, Bannister, and afterwards Cope, exhumed the body of a Dinosaur (*Agathaumus sylvestre*). Four species of Dinosaurs have also been described by Leidy, from the Judith beds (Laramie) in Montana. Still others, from this same group in Colorado, have been described by Cope.

It is therefore a fact that a Cretaceous vertebrate fauna flourished during this Laramie epoch. According to Lesquereux and Newberry, a Tertiary flora existed here at the same time, as we have already seen. Cope, summing up the evidence, remarks: "There is, then, no alternative but to accept the result *that a Tertiary Flora was contemporaneous with a cretaceous fauna*, *establishing an uninterrupted succession of life* across what is generally regarded as one of the greatest breaks in geological times." "The appearance of mammalia, and sudden disappearance of Mesozoic types of reptiles in the immediately next epoch, may be regarded *as evidence of migration*, *and not of creation.* Lizards, tortoises and crocodiles, continue from the Mesozoic through the Tertiary to our own time, without great modification of structure. The Dinosauria, however, disappeared from the land, exterminated by the more active and intelligent mammal. Herbivorous reptiles, like Agathaumas and Cienodon, would have little chance in competing with the powerfully armed mammals of Tertiary times. This transition series, therefore, of Hayden, is such in fact as well as in name; and Paleontology demonstrates his conclusion "that there is no real physical break between the well marked Cretaceous and Tertiary Groups." This rich Tertiary flora and Cretaceous fauna flourished then during this epoch also over the plains and in the lakes of Nebraska.

Coal in the Cretaceous.

No question about the Cretaceous in Nebraska is more frequently asked than this: Is there coal in workable quantity in any of the groups of this period in Nebraska? There is no question about the Cretaceous in the mountains being coal bearing. On this subject, Clarence King observes*: "In the extreme western exposures in the territory of the Wasatch and Uinta ranges, coal beds appear at the very base of the series, immediately upon the capping members of the Jura; and from that horizon to the summit of the series,

*Systematic Geology, p. 539.

throughout the whole 12,000 feet, they recur in that region. They increase in frequency after the close of the Fox Hills Group, and are most abundant through the 4,000 or 5,000 feet of the closing or Laramie Group of the series." In illustration of this statement, it is reported by Emmons that a bed of coal ten feet thick, of excellent quality, is located south of the Uinta at Ashley Creek, in the Dakota Group. Of equal excellence is another bed of coal of equal thickness in the Fort Benton Group, higher up in the series, but near the same place. Another thick coal bed, on the south side of the Uintas, is reported by Marsh, in the Niobrara Group. Coal is also reported in workable quantities in the Fort Pierre, and in still larger quantities in the Fox Hills Group. The inference, therefore, is legitimate that there were betimes, during the progress of the Cretaceous Age, extended land surfaces in this region, followed by subsidences.

Were there such subsidences and land surfaces in Nebraska during this period? Thus far none to the same extent have been found. At a few places in the Dakota Group, and also in the Fort Benton, thin beds of lignite have been found. The thickest, thus far, have been observed in Dakota and Dixon counties, where they range from six to sixteen inches, but the lignite coal is of inferior quality. As the strata are almost horizontal, and few canyons cut through them, their study in Nebraska, in the absence of borings, is difficult. It is possible, though hardly probable, that at some points in our extended territory there may be basins of coal of good quality in these deposits. Even in the mountains, the thick beds occupy depressions in the strata, and soon thin out, only to increase again in thickness farther on. To settle this question in Nebraska definitely, will require many borings, over a large area of our territory. One of the most favorable regions for testing for these lignite coals is in northern and northwestern Nebraska.

Close of the Cretaceous and Transition Periods.

With the close of the Laramie epoch, the whole series of conformable strata, which had commenced with the Dakota Groups ceased. When the last sediments of the Laramie Group had been laid down, there occurred one of the great geological revolutions in the history of the globe. From the eastern base of the mountains to the Wasatch, the whole region was thrown into a series of folds, and undulations. The Uinta Range, with its broad, flat anticlinal,

was made at this time. The whole chain of the Rocky Mountain, was lifted up, so as to leave a broad depression eastward of the Wasatch, and on both sides of the Uintas.—(King.) The Laramie Group was turned up at all angles, from a few degrees to a vertical position, as it is now found in many places beneath the superincumbent Tertiary. This upturning affected also the Cascade Range, which was then first outlined. The whole region of the plains sympathized with this movement, so that they became an extended land surface. Nebraska now certainly, for the first time since the early Cretaceous, over its whole territory became a land surface. The elevation in the mountains became sufficient to give free drainage to the sea, and exclude the oceanic waters. The great interior sea became so completely exterminated, and the continent so elevated, that it has never since been subjected to the sway of the ocean. Henceforward, fresh water lakes became dominant, down to the borders of our own times.

CHAPTER IV.

THE CENOZOIC AGE IN NEBRASKA. — EOCENE TERTIARY EPOCH.

Causes that Produced the Cenozoic Age.—Tertiary Period.—How Divided. —Eocene and Its Divisions in the West.—Eocene Not Represented in Nebraska.—Why Discussed Here.—Its Peculiar Modern Vegetable and Animal Life, and its Origin.—Vermillion Group of the Eocene.—Its Vegetable and Animal Life.—Green River Group, and Its Organic Remains. Fort Bridger Group, and Peculiar Scenery.—Its Animal Remains. Uintah Group.—Close of the Eocene.

THE culmination of those physical changes that had been in progress during the whole of the latter portion of the Cretaceous period inaugurated the Cenozoic Age. We have already seen that successive portions of the old Cretaceous sea bottoms became dry land. After the Dakota and Fort Benton groups, the first extended land surface wrested from the Cretaceous sea was the Niobrara Group. Portions of the Fort Pierre Group were next added. The Fox Hills and Laramie are not exposed in Nebraska, but both may and probably do exist in northwestern Nebraska beneath the superincumbent Tertiary. In fact, the Cretaceous period came to a close by a very gradual uplift, not of single mountain masses or chains, but by the elevation of the whole western portion or half of the continent, along with mountain folding. Heretofore the highest portion of the continent existed in the east with the Appalachian chain as the central axis; now it came to be the western portion, with the Rocky Mountains as the main axis.

The emergence of the continent was most complete towards the north. The great American Mediterranean Sea, which from the middle Cretaceous period had extended from the Wasatch to the meridian of eastern Nebraska and middle Kansas, had separated the continent into two elongated bodies of American land. This great sea had now become virtually extinct by the continued continental uprising, thus "giving free drainage to the sea, except along a basin-like depression extending from the Wasatch Range east-

ward to the meridian of 107° 30′, with a north and south extension not yet definitely known. This depression was immediately occupied by an early Eocene lake, whose northern portion corresponded with approximate accuracy to the present drainage basin of Green River. Southward it extended through portions of Utah, New Mexico, Colorado, and probably Arizona."—(Clarence King). Along with this uprising of the western portion of the continent, there was an epoch of mountain making at the close of the Laramie period, as already stated. The Wasatch and Uinta mountains were further folded and raised, and the Colorado range was greatly elevated. This folding helped to make the depression towards the Wasatch and on each side of the Uintas, which became the bed of the great Eocene lake, referred to above. This emergence towards the north, and on the west of the continent, the greater elevation of its mass, and the retreat of the seas necessarily produced great changes of climate. The mean temperature had gradually become lower, and the extremes greater. The climate also became drier. And yet it was warmer and moister than at present, as is evident from the vegetable and animal life of the time. All the old Cretaceous forms had disappeared, or had been, by changes of environment, transformed into the modern representatives. Thus was inaugurated the Cenozoic Age.

The Cenozoic Era, or Age of Mammals, comprises two periods, namely: First, The Tertiary; second, The Quaternary.

Tertiary Period.

Lyell divided the Tertiary into three divisions, which were named from the number of species of fossil shells which they contain, and which are living in existing seas. They are the Eocene, Miocene and Pliocene. Other divisions are in use in the east and south, but as Lyell's method is most convenient, and his divisions the most characteristic of the west, they are followed in this work.

Eocene Epoch.—As already stated, there are no deposits of this period in Nebraska. During the whole of it, Nebraska was an extended land surface. The forces that had finally lifted the continent from the embrace of the sea, during the closing centuries of the Cretaceous period, had extended their work to the region of the plains, and made them dry land. During the whole of the Eocene, therefore, Nebraska was an extended land surface. What really occurred here during this period, can only be inferred from the veg-

etable and animal life that is found entombed in the Eocene beds of the mountains. The record there is comparatively full—here there is none whatever. At the present day nearly 500 species of Nebraska plants grow in the mountains, and on the foot-hills. The proportion of animals common to the two regions is still greater. In Eocene times the differences in level and climate were probably not near so great as now. It is therefore highly probable that the larger number of vegetable and animal forms that then flourished around the shores of this old Eocene lake in the mountains, also lived in Nebraska. Unfortunately, many species, also, that then existed here did not range so far west, and therefore no memorials of their presence have been preserved.

Clarence King has recognized four groups of the Eocene, which he has named as follows:

1. *Vermillion Creek Group.*—This is the *Wasatch Group of Hayden.* Lowest Eocene, 5,000 feet thick.

2. *Green River Group.*—Hayden and King. Middle Eocene, 2,000 feet thick.

3. *Fort Bridger Group.*—Hayden and King. Lower and middle horizon of the upper Eocene, 2,500 feet thick.

4. *Uinta Group.*—King. Upper Eocene, shading into Miocene, 500 feet thick.

In these groups we have the most complete memorials of the higher land and fresh water life of the Eocene of the continent. The Gulf Alabama Eocene beds are much less complete, as they begin at a much higher horizon than the Vermillion beds. As the Eocene is not present in Nebraska, I will omit the lithological and physical description of these beds, referring only to such particulars as may throw light on Nebraska's geological history during those times.

The Length of the Eocene Epoch was very great. This is inferred from the 12,000 feet of sediments that were accumulated in the bottom of the Rocky Mountain Eocene lakes. Many of the sediments of the Green River and Fort Bridger groups are of the character that accumulate with extreme slowness. A large part, too, of the upper beds, where they constitute the surface rocks, has been removed by erosion. Their original thickness, therefore, must have been much greater than at present. The estimates of time, however, are made from the remnants of these beds. It has been estimated that at the most rapid rate, not more than one-fourth

of an inch of solid sediment, on an average, could accumulate in a year. It was probably far less rapid than that, but even at that rate, over half a million of years were required to accumulate these 12,000 feet of sediments that are left from these old lake beds. During the progress of these deposits, there were occasional oscillations of level and interruptions in the accumulation of materials. This is indicated by the shifting of the shore lines westward, and the slight unconformability of the Green River beds with the underlying Vermillion.

We can best understand the progressive movements, and the advanced position of those times by considering the vegetable and animal life which is found entombed in its various groups.

It was the great changes in climate resulting from the changes in physical geography, that either exterminated the vegetable and animal life of the preceding Cretaceous period, or by gradual change of environment transforming them into the advanced stages which they exhibited during the opening centuries of the Eocene.

Life during the Vermillion Creek Period. Wasatch of Hayden.—In the sediments of this group (5,000 feet thick), have been found, and described by Lesquereux, forty-six species of plants. Among these are found the following notable forms: One Cypress (*Taxodium dubium*), one Giant Cedar (*Sequoia Heerii*), one Sweet Gum Tree (*Liquidamber gracilis*), six species of Cottonwood (*Populus*), one Alder (*Alnus Kefersleinii*), one Birch (*Betula Stevensoni*), five Oaks (*Quercus*), two Hazel-nuts (*Corylus*), two Beeches (*Fagus*), five figs (*Ficus*), two Sycamores (*Platanus*), two Dogwoods (*Cornus*), one Magnolia, one Papaw (*Asimina mioceneca*), one Grape-vine, three Walnuts (*Juglans*), and twenty-one other species. These vegetable forms, according to Lesquereux, are, when compared with European fossils, all of Miocene type, though found here in the lower Eocene. In fact, of the fifty-six species, thirty-one are identical with the European Miocene, or the Arctic Miocene Flora. According to the same authority, they are indicative of a warm temperate climate. This is specially indicated by the presence of the Magnolia, Fig Trees, Sequoias and Cypress.

Animal Life of the Vermillion Group Epoch.—The peculiarity that marked the animal life of the earliest Eocene was the sudden appearance of mammals of a high type. Though highly generalized compared with their more modern representatives, the transition forms connecting them with the animals of the preceding Cretace-

ous period are unknown. If the period of transformation was the preceding Laramie period, which is regarded by Hayden as a transition group between the Cretaceous and Tertiary; then the evolution of their forms occurred elsewhere, where no records have, been preserved. It probably, however, was near by, and may have been the region of the plains in Kansas and Nebraska; and if so, during the early Eocene they came by migration around the shores of the Vermillion lake, in whose sediments their remains were preserved.

The distinguishing peculiarity among the mammals that now appeared in large numbers was the tapiroid features that marked them all. They were mostly odd toed (*Perissodactyls*), like birds and dinosaurs. It has been observed by zoologists that as dinosaurs in the character of the sacrum, vertebra, ischium, etc., were related to, or had mammallian characters, so the tapiroid mammals of the Eocene had also dinosaurian features. The dinosaurs were still more closely in their organization related to birds, so that it is uncertain of many of them whether they were most reptile or bird. It is possible, therefore, that at some time along the transition periods of the Mesozoic the dinosaurian branch divided, one part proceeding towards or transforming into birds, and the other into the mammalia.

Among the lower Eocene Vermillion animals Cope has described three small species of carniverous animals, having more or less of the then common tapiroid characters.

The hoofed (*Ungulata*) animals are, however, the most interesting. Fifteen species of these are from this group. Six of them belong to the famous Dawn Horse Family (*Eohippus*), and have been described mainly by Marsh. They were about the size of a fox, and had three toes on the hind foot and five on the front, four of which were serviceable, and one splint (*metacarpei*) that did not touch the ground, but probably carried a rudimentary thumb toe, "like a dew claw." Unlike the modern horse, "the bones of the leg and forearm were not yet distinct."—(Marsh.)

The Vermillion beds from which these animals were procured have been called the *Caryphodon beds*, from the presence of remains of animals that have received that designation. These peak-toothed animals (*Caryphodons*), of which four species have been described, were peculiar in their highly generalized type of foot and tooth structure. They had five hoofed toes, and their general structure

connected them with tapirs and such generalized carnivores as bears. *Coryphodon elephantopus* was about the size of a small elephant, but some of the species were much smaller than the modern tapir.

Another group of animals described from these beds by Marsh, were named *Tillodontia*. Like the preceding, they were highly generalized in structure, and combined the hoofed toes of the *Ungulata* with the head of the bears and the incisor teeth of the rodents. Thus far four clearly defined species have been described. Among reptiles several species of crocodiles and many turtles have been obtained.

Green River Group.—This group is unconformable to the preceding, indicating some changes of level preceding its deposition. It overlaps the Vermillion group towards the west at least 200 miles (King). The sediments that constitute this group are 2,000 feet thick, and are exceedingly fine, indicating their deposition in deep waters. In some localities, such as Barrel Springs, south and east of Cathedral Bluffs, the shales of this group are extremely carbonaceous, and are intercallated with fine, sandy members. Many leaf impressions are found in them, and numerous fresh water shells.

Vegetable Remains of the Green River Group.—Lesquereux has described 82 species of plants from this group, but their general facies is remarkably distinct from that of the preceding deposits. Among these plants are six ferns, two species of Equisetae, eleven conifers and nine grains and grasses (*Glumaceæ*). The willows (*Salix*) were represented by three species, the oaks (*Quercus*) by five, hollies (*Ilex*) by four, sumac (*Rhus*) by two, and walnuts (*Juglans*) by six species. Fig trees, the cyprus, the giant cedars, and the ash were still present, but the palms were gone. It contains only a remnant of the Flora of the preceding group. Lesquereux, in studying this Flora, came to the conclusion that it represented a vegetation characteristic of "high land, covered with lakes, swamps, and deep forests of conifers with a thick undergrowth of ferns and shrubs." In the Tertiary it has its analogue with the Flora of Oeningen in Switzerland, or upper stage of European Miocene. As this vegetation is an upland flora, it is probable that it does not so fully represent the vegetable forms that obtained on the plains of Nebraska during this period as the preceding Vermillion Group epoch.

Animal Life of the Green River Group.—As already stated, fresh water shells were exceedingly abundant. Fish seemed to be enormously abundant, at least in individuals, though the number of genera represented are comparatively few. One of the commonest of genera is Clupea, of which some half a dozen of species have been clearly distinguished. Our existing, shad and herring belong to this group. Several other genera, each represented by from one to seven species, have been described. Turtles were abundant in this old lake. But with the exception of a crocodile described by Leidy, about the size of the one living in the Nile, the higher reptiles of the period were not preserved. In mammallian life it does not compare with the preceding or the next group.

Fort Bridger Group.—The areas of the Bridger beds are surrounded by strata of the Green River formation, which pass under them, exhibiting slight nonconformity.—(King.) They are 2,500 feet thick. "The materials are largely made up of almost uniform buff and gray marls, and clays, interrupted at several horizons by beds of peculiar green earth." "Fine sand and clay predominate, arranged in varying proportions, and occasionally changed by calcareous admixtures. It is a sand and clay formation, while the preceding Green River group is highly calcareous." The Bridger beds are intricately eroded into all kinds of fantastical architectural forms. At and near Cherokee Ridge a line of bold escarpments extend northeast for fourteen miles. Here the Bridger beds rise 300 feet above the level valley, and present many abrupt, nearly vertical faces, worn into innumerable architectural forms. Often outliers stand detached in bold, isolated blocks, which have been sculptured by the winds into many singular forms. Sometimes enormous masses project from the main wall, the stratification lines being traced by the creamy, gray and green sands and marls, which resemble courses of gigantic masonry. Narrow galleries often project far into these labyrinths. The whole appearance is like a line of Egyptian structures. Among the most interesting forms are the isolated blocks, often over 100 feet in height, which are the last relicts of the beds which once covered this region. The plains skirting these "Bad Lands" are quite level, there seldom being any talus at the bottoms or base of the cliffs. The excessive fineness of the materials is leveled by the water agencies that have for so long a period been producing erosion.—(King.)

The Bridger beds are most remarkable for the animal remains which they have preserved, and which has made them classic ground for the geologist. From the above description it is seen that they are eminently adapted for the preservation of animal remains. At the foot of almost every cliff can be found some remains of turtles or mammals.

Animal Life of the Fort Bridger.—Moluscan life was abundant, but I can only refer to the vertebrate, and especially to the mammalian life of the time.

Fishes were represented by numerous forms, among which were species of *Phineaster*, closely related to the modern catfish, several species of gars and many kinds of mud fish, as *Amia*. Closely related to the last are numerous species of Pappichthys, some of which are classed by Marsh with Amia. Marsh has also described many species of serpents, one genus of which (*Boanus*) was allied to our water snakes. The saurians were represented by many species, which have been mainly described by Leidy and Marsh. The most abundant of these are the crocodiles, of which at least six species have been defined. Many others, closely related to the crocodiles, are found in the same localities, among which the Glyplosaurus and Thinosaurus were also described by Marsh. The turtles (*Chelonia*) were also present in large numbers. Species of the genus Emys were most abundant, though there were also many of the soft shelled kind (*Trionyx*), and of several other genera. Some of them were small, but many of them were of gigantic size. Some of the land turtles of the genus Hadrianus, described by Cope, were from twenty-five to twenty-nine inches in length, and proportionately broad. They were probably the largest of all the extinct land tortoises.

True birds seem to have been abundant. One of the first described from this group was a form allied to an owl, and called by Marsh Bubo leptosteus. One genus of waders (*Alletornis*), was represented by five species. The remains of a woodpecker (*Uintornis leucaris*), have also been described by Marsh.

The highly generalized Tillodontia, that appeared already in the Vermillion group, were here represented by several genera. Of these, species of Tellotherium were the most abundant. With these fossils are mingled many species of rodents.

The hoofed odd-toed (*Ungulata*) animals were present in great numbers. One of these genera, of which several species have been de-

scribed by Leidy, he has named Paleosyops paludosus. It had forty-four teeth, and formed nearly an unbroken arch. The canines were proportionately as large, and of the same form as in the bears. It was about the size of the existing tapir of South America. In the structure of the mouth and teeth it resembled the Paleotherium of the European Eocene. From the structure of its mouth, Leidy concludes that, like the bears, it was omniverous. Another species (*P. major*), was as large as the Indian Rhinoceros. Several other species have been described. A still more curious species, described by Leidy, was the gnawing hog (*Trogosus*). The two species ot this genus combined the characters of the tapirs with those of the gnawing animals. The incisor teeth did not extend so far back as in the rodents, and in this respect approached the hog and pecary. Unlike the rodents, however, the worn slope of the incisors is directed both backwards and forwards. No canines existed approaching in this respect the Hyrax, Mastodon, Elephant and Rhinoceros.

Another tapir-like genus of animals was the *Hyrachyus*, of which six species have been described by Leidy, Marsh and Cope. They differed from the South American tapir only generically, and averaged about the same in size. From the great numbers of their remains, they must have been exceedingly abundant during this period. Thus one of the animal forms most common in North America in Eocene times still persists in the tropical regions of this continent. Many other genera of tapiroid species have been described from this basin to which I cannot even allude.

The Mountain Horse (*Orohippus*), similar to the Eohippus of the Vermillion beds, but wanting the fifth toe, is also found in this group.

Perhaps the most remarkable mammals yet discovered in rocks of any geological age, are the *Dinocerata*, which received that name from Marsh, who regards them as the type of a distinct and new order. He gave them this name because of the peculiarities of their heads, which were armed, some of them with three and some of them with two pairs of horns. They were "terribly horned." Cope, on the other hand, does not attach the same weight to these characters, and merely considers them to be a sub-family of the elephants (*Proboscidians*). He claims that they had trunks similar to the elephants. Marsh denies this, on the ground that the naral opening and general structure of the head unfitted it for carrying a large trunk or proboscis, and because their short limbs and longer

necks enabled them to reach the ground for food without the help of such an appendage. The heads of most of the species were extremely elongated, but the limbs bore a striking resemblance to those of the elephants. One pair of horns, of small size, was placed above the nasal bones, far forward; the second pair, somewhat larger, above the canines on the maxillary bones; and a third pair, of large size, on the parietal bones, far back on the head. Large canines from the upper jaw extended in a slight curve downward, varying in length, on the different species, from five to ten inches. They had no incisor teeth.

Cope recognizes four genera of these remarkable animals. Leidy first made them known in his description of Uintotherium, of which three species at least are now known. Subsequently Marsh and Cope described other genera and species, and no little confusion has been produced by the different names ascribed by different investigators to the same species. Cope's type genus, and species is Loxolophodon cornutus (*Tinoceras grandis*, Marsh). This species is perhaps most remarkable for the narrow form of the cranium, which at its middle is only one-fourth its length. The horn cores diverge, "having in their upper portion an outward curvature." * * "Its form and proportion of body was similar to that of an elephant," but its limbs were shorter, and its tail was quite small. The neck was longer than that of the elephants, but shorter than that of the rhinoceros. The hind pair of horns towered far above the others, "extending vertically, with a divergence when the head was at rest." Cope, contrary to Marsh, claims that the muzzle could not have reached the ground by several feet, and that therefore a proboscis, as in elephants and tapirs, was a necessity. The horns were probably palmate.

Eobasileus is another genus of the family established by Cope, but which may be included in the preceding. It was about the same height as Loxolophodon, but more slender. The muzzle, too, is shorter and more contracted, as also the horn sheaths. Still another genus of this remarkable family, described by Leidy, was Megaceratops. It was about the size in bulk of body to a small elephant.

~~The Bathmodon~~tidæ were a group of animals closely allied to the preceding. Cope has described four species from deposits of this age. The neck was longer and the dentition more complete than in the preceding forms of this order. They stood in even closer relation to the odd-toed animals than even the Eobasileus.

This is the same as Coryphodon

The Insectivera (animals with molars having short points) were, represented by many genera and species, indicating a great fullness of insect life during the early Eocene times.

The Carnivora were already abundant. They were like the preceding orders, of a remarkably comprehensive type. One of the most curious was the Mesonyx abtusidens, described by Cope. It was as large as our timber wolf, but with a more slender body behind. The cheek bones were more prominent than in the wolves and the tail more like that of the dogs. The phalanges of the first series were elongated and curved, as in the cats, but like the dogs it walked on its toes (*digitigrade*). The foot, moreover, was short, and the claws flat and more adapted to aquatic use than prehensile (*grasping*). The number of its molars exceeded that of any recent families of carnivora. The teeth, though sectorial, are not so to the same extent as in existing carnivora, the cutting edge being dull and uccupying but half the crown. While, therefore, dog-like, it had many characters relating it to other families. Still more curious was an animal called by Cope Synoplotherium lanius. Its claws approximated in character to the seals. The lower canines projected forwards, and were of large size and came so close together that there was no room in front for the incisors. They, however, rested against the incisors of the upper jaw, and latterly against the upper canines. In other particulars, this animal resembled the bears and the hyænodons that appeared in the next or Miocene epoch. The peculiar approach and projecting form of the lower canines, was doubtless, as Cope has suggested, a modification of structure for special habits, which was the destruction and devouring of turtles, which so wonderfully abounded on land, lake and sea, during early Eocene times.

Sinopa rapax was an animal that was intermediate in position between the wolves and the dogs, and about the size of the red fox. Canis montanis is described by Marsh as a species of wolf, larger than the grey wolf.

Patriofelis ulta (Father of the Cats?) described by Leidy, was related to the panther and the dog family, with some characters approaching the weasels and civets. It was considerably larger than the former.

The Quadrumana, the order to which the monkeys and man belongs, were represented during this period by at least eight species, among which the following were characteristic forms. Timotheri-

um had a long thigh, free from the body, a forefoot capable of being set down flat, and a form of lower jaw and teeth, similar to that of the lower modern monkeys. The form of the humerus and its relative length to the femur, resembles that of the lemurs. * * "The greatest difference is that of the increased number of teeth, which related them in this respect to the ancient carnivora and ungulata," all of which had more teeth than their modern congeners. (Cope). The genus Anaptomorphus represents a group more nearly related to the existing types of Madagascar and South Africa. None of these quadrumana of the Fort Bridger Group are typical forms, and all are much more generalized than existing families.*

The above species represent only a very small number of the extinct species found in this group, but they will serve to give some idea of the remarkable life that flourished during those times—times "when the existing orders of the mammalia were yet in process of differentiation, and were scarcely distinctly defined."

UINTA GROUP.

South of the Uinta Mountains there is a small group of Tertiaries, about five hundred feet thick, which constitute the closing deposits of this period. They have been called the Uinta Group by King. The materials at the bottom are gritty, rough conglomerates, shading upward into finer grained sandstone, and at certain points into beds of creamy, impure limestone. "The strata seem to form an unbroken line from the region of the Wasatch eastward through the length of Uinta Valley, across Green River, into the valley of the White River. The animal remains which are found in this group, especially in White River Valley, belong to a more advanced Eocene period than the Bridger series. They contain some forms approximating to the lowest Miocene types."—(King.) It is not improbable that these beds represent the transition period between the Eocene and Miocene. Among the important vertebrates of this series are the following:

Hyopsodus gracilis was a small animal, related in many of its characters to the hog family. It was of small size, and retained some tapiroid elements. Epihippus Uintensis and E. gracilis were small, horse-like animals of this period, closely related to the orohippus of the Bridger beds, but showing a structure approximating to the Mesohippus of the next or lowest Miocene period:

*For a full technical description of the extinct mammalian species of the Eocene of the Rocky Mountains, the reader is referred to the reports of Leidy, Marsh and Cope.

Agriochœrus was a genus of hog-like ruminants, that flourished during these times. It was related to the Oreodon of the Miocene. It differed from the latter and from all known ruminants in having the orbits open behind.—Leidy.

This group closed the deposits of the Eocene period. This region of lakes had been rising during the latter portion of Eocene times, and their final extinction closed this period.

CHAPTER V.

THE TERTIARY PERIOD, CONTINUED.—MIOCENE EPOCH.

Inauguration of the Miocene Epoch.—Formation of a Lake on the Plains.—Boundaries.—Where the Miocene is Exposed in Nebraska.—Extent.—Miocene Lakes farther West.—Basin Region.—Oregon Region.—An Age of Lakes.—Name of the Eastern Lake.—Kinds of Rock.—Whence the Materials were obtained.—Why the Miocene Beds are Thin on the Plains.—Length of the Miocene Epoch.—Bad Lands.—Flora of the Miocene.—Animal Life.—Insectivora.—Rodentia.—Horse Family.—Titanotheriums.—Symborodons.—Mastodons and Elephants.—Rhinoceros'.—River Horse.—Hog Family.—Camel Family.—Musk Deer.—Oreontidae.—Carnivora.—Hyaenodons.—Drepanodons.—Quadrumanna in the Miocene.—Mammals in the Miocene, not Described nor Found.—Closing of the Miocene Epoch —Its Gradual Characters.—Lava Floods at the Close.—Formation of the Coast Range.—Farther Depression of the Plains.—Effect on life of these Changes.

THE Miocene Epoch was gradually inaugurated. During the Eocene Epoch the plains were an extended land surface, made up of the eroded materials of the Cretaceous and the Permian and Carboniferous rocks. There was free drainage to the sea, but of the rivers and their tributaries of that time, we know nothing. The upward movement of the plateau regions that eventually drained the old Eocene lakes was accompanied by a subsidence of portions of the adjoining plains. The old mountain lakes were shifted eastward, the depressions in the plains making room for them. While the mountains went upward, the plains went downward, like the changing waves of the sea. As this movement was slowly in progress for ages before it was consum-

mated, the probabilities are that the great Miocene lake of the plains commenced to form before Uinta lake had terminated its history. There probably were no great convulsive throbs of the earth's crust, separating sharply the two epochs. The Eocene shaded into the Miocene epoch. This lake of the plains extended from near the north line of Kansas across Nebraska, a large part of Dakota Territory, west of the Black Hills, and northward to Manitoba. Its exact geographical extent has not been ascertained in Nebraska, owing to the superincumbent Pliocene, which overlaps it, and through which it only projects at intervals. The best exposures in Nebraska commence on the Niobrara River, about 300 miles west of the mouth of the Keya Paha or Turtle Hill River, and extend to the west line of the State, taking in the White Earth River region and the space between the latter and the north line of the State. It is finely represented on and north of the latter river in Dakota Territory, constituting there a portion of the famous Makoo-si-tcha or Mauvais Terre of the French, which has been rendered into English by the term Bad Lands, although in the Dakota tongue it means simply a country hard to travel over. On the west the Miocene abuts against the undulating surface of the Laramie Group, and therefore did not extend quite to the foot-hills of the Colorado Range. The extent of this great fresh water lake has been variously estimated at from 100,000 to 130,000 and upwards of square miles.

The loeal subsidence of the plains on the east, next to the mountains, was accompanied by a somewhat similar depression between the Wasatch and the Sierras, forming also a large Miocene lake in that region. Another great Miocene lake extended from Washington Territory through Oregon to Nevada and Colorado. In eastern Oregon, the deposits of this epoch are enormously thick, the depth reaching 5,000 feet, overlaid, however, by the lava beds, which were poured from fissures at the close of the Miocene. It does not fall within the plan of this work to discuss any of these old Miocene lake beds except the one covering a portion of Nebraska.

From the above it is seen that the Miocene was pre-eminently an age of great fresh water lakes. It is questionable whether on this continent any other geological epoch was represented by such a number and such large basins of fresh water.

Clarence King has suggested for the Miocene lake that extended through Nebraska the name of Sioux Lake. Hayden, who first studied these beds in this region, called them the White Earth River Group.

Kinds of Rock.—The materials of these Miocene beds vary a great deal in character. This would naturally be expected in a lake bed which received the drainage, through countless ages, of the rivers that now have their outlet through the Missouri. Varying currents and other conditions would naturally frequently change the character of the sediments deposited on the bottom. The rocks that supplied the materials that were carried into this Miocene lake evidently came from the Archæan nucleus of the Rocky Mountains and the Black Hills, the Palæozoic, the Juro-Trias and the different groups of the Cretaceous. The eroded materials going seaward were stopped in these old lake beds. Erosion, however, through the Miocene, was by no means as rapid as at present. The height of the plateau region was much less than at present; the atmosphere was moister, the rainfall much gentler and more constant, and a warm, temperate climate obtained. The extreme cold of winter, which is such a mighty agent in the disintegration of rock, and which now characterizes these regions, did not then exist. Hill, valley, plain, mountain and plateau, were also covered by dense growths, in places, of grasses, and in places of mighty forests, which protected the land from the denuding agencies which are now constantly at work. As already stated, the extreme thickness of the Miocene in the West reaches its maximum in Oregon, where beds 5,000 feet in vertical thickness are found. Owing to the causes alluded to above, on the plains the Miocene beds are comparatively thin. Meek estimates their thickness at from 530 to 600 feet. Where I measured them, on the Upper Niobrara, they rarely exceeded 400 feet.

If we calculate the length of Miocene times on the same principle as Eocene, this epoch was probably a quarter of a million years long. It should be remembered, however, that there is no certainty about the length of geological periods.

In Nebraska, on and north of the White Earth, and on the Upper Niobrara, the rocks of the Miocene have the following character: Indurated grit, of a reddish brown color, with occasional layers of concretions of silicate of lime, often shading into, first, a coarse and then a fine green sandstone. Above this occur, sometimes, im-

mense masses of conglomerate, with occasional layers of tabular limestone. Then come coarse-grained sandstone, often loose and friable, and sometimes compact and heavy bedded. A limestone layer, followed several miles, often changes into a silicate of lime, then sandstone, and then conglomerate, and the opposite. The sections published by Meek, Hayden and Leidy correspond, in the main, to the above.*

Bad Lands.

A portion of this old Miocene lake bed, on and north of the White Earth River, as already stated, now constitutes the Bad Lands. This is one of the most wonderful regions on the globe. Here, at present, there is very little, and in some places formerly there was no vegetation. Water fit to drink is exceedingly rare. This region is worn into labyrinthine canyons that wind around in in every conceivable direction. Occasionally only isolated, sometimes almost perpendicular, portions of the original beds remain, producing the appearance of abandoned human habitations, or old desolated, forsaken oriental cities. Climbing some of the heights, far as the eye can reach, there seems to be an interminable array of towers, spires. cathedrils, obelisks, pyramids and monuments. "Not unfrequently the rising or setting sun will light up these grand old ruins with a wild, strange beauty, reminding one of a city illuminated in the night, when seen from some high point." The harder layers project from the sides of the canyons, or mimicked architectural forms, with such regularity that they appear like seats, one abve the other, of some vast weird amphitheater. It is here among these strange, grotesque ruins, that the remains of the unique animals, described farther on, are found."—(Hayden). To the geologist, no region is so inspiring, though in summer time he will often find the heat almost insupportable, as the sun heats up these bare walls like an oven. I have been among these ruins when the thermometer ranged from 108° to 115°. So great, however, is the interest that is inspired by this page in the earth's history, that the naturalist gladly braves the hardships of travel among these desolations.

As can be inferred from the preceding, during the Miocene epoch the greater part of the eastern portion of Nebraska was a land surface.

*See Leidy's Extinct Fauna of Dakota and Nebraska, page 16.

Life of the Miocene.—The fossil remains which are found in this old Miocene lake bed indicate the life of those times. I can only point out by a few examples some of its salient points.

Not the least remarkable was the flora of the Miocene. In my excursions to northwestern Nebraska, I found traces and impressions of many land plants, but unfortunately they were too fragile to remove them from the containing matrix, and all attempts to accomplish it resulted in their destruction. Among those identified were cottonwoods (*Populus*), willows (*Salix*), magnolias, oaks (*Quercus*), sweet gum trees (*Liquidamber*), sassafras, our southern cypress (*Sequoia*), Glyphtostrobus, which is closely allied to the preceding, palms, fig trees (*Ficus*), lindens, birches, maples, pines, etc. Other observers in other regions have observed many more species, and have especially noted the vast abundance of the Sequoias and their congeners which abounded in Miocene times, not only in America, but over the whole of northern Europe and Asia, and even in Greenland, Iceland and Spitzenbergen.* The forms, however, that Heer describes from Greenland, Dawson supposes to be of the Eocene Age. However that may be, it is clear that in Nebraska there flourished in Miocene times trees of the same gigantic character and even of the same genus, and probably of the same species, as now grow in the sequestered vales of California. Some of the United States geologists have, indeed, expressed the conviction that in that age Nebraska was covered by a vast savanna. I take the opposite ground, because of the occurrence in the Nebraska Miocene beds of many species of trees. Besides these giant cedars that here loomed heavenward, there were species of palms and fig trees, as stated above, and these helped to give the vegetation that warm, temperate, or semi-tropical aspect which marked its facies as a whole.

Animal Life.—Along with this warm, temperate flora, there existed in Miocene times a still more wonderful animal life. Perhaps never have the conditions for mammalian life been so favorable as during this epoch. The few that can be noticed in this chapter can simply illustrate its general character and richness. The insectivora, which were represented by several genera and species, must be passed over. Among the rodents the rat family was already represented by a species called by Leidy, Eumys elegans. A

*See on this subject Gray's Address to the American Association, Gray's Forest Geography, Saparta's Anænne Vegetation Polaire, Heer's Flora Arctica.

beaver (*Palæcaster Nebrascensis*), was also abundant at this time. The squirrels of that time were large, as is indicated by the remains of Ischyromys typus, whose head was larger than that of a musk-rat. The rabbit of the Nebraska Miocene was smaller than the common species of the State at the present time

The horse family (*Solidungula*), which is now represented by one genus (*Equus*), whose characteristic species are the horse and the ass, was rich in genera and species during the Miocene. We have already seen that the family came into being in the early Eocene, the first known characteristic form being the Eohippus. In the early Miocene we already have the Mesohippus, represented by several species whose distinctive peculiarity was that the fourth toe had become a rudimentary useless splint. Next in the Miocene came the Anchitheriums, which were represented in Nebraska by one species, with three additional forms in Colorado. The peculiar feature of these horses was that they had three toes, all of which touched the ground, the two lateral, however, being comparatively small and weak. Closely allied to these were the Hyperions, several species of which lived during Nebraska Miocene times. They also had three toes, but only the middle one touched the ground, the two lateral swinging not much unlike the two side toes of the hog, being, however, comparatively much smaller. Another genus, Merychippus, was closely related to the preceding. These Miocene horses ranged in size from an animal much smaller than the ass to animals about the size of a small modern horse. It is seen, therefore, that at least four genera of horses existed in Miocene times, each genus, however, being represented by from one to several species. They must have been exceedingly numerous, and doubtless roamed over our plains in countless numbers.

Another peculiar family of odd-toed animals that existed in Miocene times were the Titanotheriums. Leidy first described and named them. So abundant are their remains at one horizon in the lower Miocene that it has given it the name of Titanotherium bed. Marsh afterwards described a closely related animal by the name of Brontotherium. Subsequently Cope described another of the same family by the name of Symborodon. Megaceratops Coloradoensis, of Leidy, belongs to the same group. These animals had the same bulk of body of the elephants, and united the characters of the rhinoceros and elephants with more distant affinities to the Dinocerata of the Eocene. The head was extremely elongated, and be

cause of its depression in the middle, bore some resemblance to a pack-saddle. They probably had a small trunk about as long as that of the tapirs. They had two pairs of horns, one pair being above the nasals and another pair above the eyes, the hind pair being powerful weapons of defense. They probably were the successors of the Dinocerata of the Eocene. Of the Symborodons Cope has described five species. As two species of Brontotherium were also described by Marsh, it is clear that the number of species was great, and judging from the remains, there must have been a very great number of individuals.

Along with the Symborodons the elephants and mastodons were already represented by several species. The remains of the one that I found on the White Earth, in Nebraska, were too much decayed to identify specifically. It bore the closest resemblance to the Mastodon merificus that appeared during the next or Pliocene epoch.

Among the most unexpected of all discoveries in the Nebraska Miocene was the remains of rhinoceros'. One, the Rhinoceros occidentalis, was about three-fourths the size of the Indian rhinoceros. R. Coloradoensis was found in the Miocene of the mountains.

The curious European genus of river horses (*Hyopotamus*) was represented during those times by at least one species. It had affinities relating it to the hog family.

Genera closely related to the hog family (*Suidæ*) were abundant during this epoch. One of these genera (*Elotherium*), which was first described from the Miocene of France, was represented by several species during these times in Nebraska and Dakota. Its nearest allies among existing animals are first the hogs, and then the peccary and hippopotamus. One of these (*E. Martoni*) was about the size of a large hog, while another (*E. ingens*) was at least one-third larger. The peccaries, which are now confined to South America and the southern United States were represented in Nebraska during the Miocene by several species. Five other genera of the Suidæ occur in these deposits. During this period, therefore, it is evident that suilline animals existed in great numbers all over the land.

The most curious fact, perhaps, connected with the animal life of this epoch, was the presence of many species of the camel family. At present it is confined to Asia, Africa and South America. In the former it is represented by the camel proper, and in the latter

by the Auchenia or Llama. In Miocene times, however, they were represented in Nebraska by several genera and many species. One of the first, described by Leidy, was called Pæbotherium Wilsoni. It was only about as large as the domestic sheep. Protomerys Evansi was closely related to the preceding, and about the same size. A musk deer (*Septomeryx*) Evansi, also occupied this territory at this time. It had many characters, especially in the form of its maxillaries, relating it to the deer. It was about the size of the musk ox of Thibet.

No family of animals was represented in that epoch by more genera, species and individuals than the Oreontidæ. Leidy, who first described them, called them ruminating hogs. The skull approached more nearly to that of the peccaries, though the upper part had some characters uniting them with the camels. The molars were like those of ruminants, and resembled most nearly those of the deer, but unlike modern ruminants, they had incisors in both jaws. The canines resembled most nearly those of the hog. The teeth, as a whole, formed an almost unbroken arch, a condition found in few animals besides the quadrumanna. Like the hogs, too, they had four toes on each foot, two being functional, and the two on the sides being too elevated to touch the ground. They were, therefore emphatically what Leidy called them, ruminating hogs. They were, judging from the abundance of their remains, more numerous than any animals of those times. They were gregarious, and must have roamed over eastern Nebraska in countless millions. In size they ranged from an animal not larger than a raccoon to one as large as a small elk. The most abundant was Oreodon Culbertsonii. It was slightly smaller than the domestic sheep. I have occasionally seen a stratum in the Bad Lands which in places was largely made up of their remains. The largest species was probably O. superbus, whose skull was fourteen inches long. Besides the many species of Oreodon at least five additional genera of this family are known. The number of species clearly defined of all the genera was not less than twenty-five. These animals were, therefore, among the characteristic features of the Miocene epoch, and during those times could probably have been found everywhere in America.

The herbivora, however, did not hold undisputed possession of the land. The happiness of these countless herds was interrupted by most sanguinary enemies. The carnivorous mammalia were

present in numbers proportionate to the herbivorous animals. Among these the most blood-thirsty were the *Hyænodentidæ*. They were first described from the Miocene of France by Cuvier under another name. Subsequently four additional species were found and described by De Laizer and De Parieu under the above family name. The three distinct species found in the Bad Lands by Evans, Shumard, Meek and Hayden were described by Leidy. "The genus Hyænadon combined the characters of the wolf, tiger, hyæna, weasel, raccoon and opossum."—(Leidy). It was, therefore, one of the most comprehensive types of carnivorous mammalian animals that ever existed. The largest of the species was M. horridus, and was about the size of the largest of the black bears. The dentition of this animal was the most formidable conceivable. "In addition to powerful canine teeth, three of its molars were structured after the single sectorial tooth of other carnivorous mammals, though the last alone reached the full development of the corresponding tooth of the latter. The last of the series of molars were formed like those of the lion and tiger. These teeth—the strongest and broadest—combined the mechanism of the wedge and scissors, and were eminently adapted for cutting tissues and bones. Immense temporal fossæ occupied the sides of the skull for the attachment of the powerful muscles that operated the levers that moved the lower jaw. The skull was about a foot in length. No animal living contemporaneously with this formidable creature could have resisted its power."—(Leidy.) Next in size was M. cruentus, and smallest was M. crucinus.

Among the carnivora of the Nebraska Miocene the cat family (*Felidæ*) were well represented. Among the most remarkable of the family was a genus of saber-toothed lions (*Drepanodon*). Its remains were first found in Western Europe, afterwards in Greece and Asia, and finally in both Americas. The largest species equaled the lion and tiger in size, and judging from their terrible array of destructive teeth were even of greater ferocity. In comparison with the existing cat family they were characterized by a greater proportionate size and flattened form of the upper canine teeth, which has given these animals the name which they bear. Drepanadon occidentalis was about the size of the existing panther. D. primævus was slightly smaller. Two of the skulls found by Hayden exhibit marks of a conflict with some other carnivorous animal and probably the largest Hyænadon, as the canines of the

latter fit exactly into the depressions or holes found on opposite sides of the specimen. No doubt these animals had a fight in some of the beautiful valleys that drained into this Miocene lake, and then, after their death, their bodies were carried into it by some flood. Closely allied to the last was the saber-toothed weasel, so-called because the number and disposition of its teeth were the same as that of the weasel. Leidy called it Dinictis. It differed from the Drepanodon principally in the possession of two additional molar teeth to the lower jaw. This animal was slightly smaller than the panther, and about as large as the smaller contemporaneous Drepanodons, whose formidable upper canines it also possessed. Its remains were first found by Hayden in the Bad Lands of Dakota, but molars of the same I subsequently obtained from the White River, in Nebraska. Cope has obtained additional genera, allied to the above, from Colorado. He has also described from the Miocene of Colorado several species of the dog family (*Canidæ*), mostly, however, of small size. I have found a few of their teeth in the Miocene of Nebraska, but from the paucity of the materials, I was unable to identify them specifically.

If, as Cope supposes, the Leptochœrus of the Bad Lands was most closely allied to the quadrumanna, then the monkeys were here during the Miocene epoch. He has also described several species from the Colorado Miocene. One of these he has named Menotherium lemurinum, because of its close relationship to the modern lemurs. It was about the size of the common cat. I infer their presence in the Nebraska Miocene from the discovery on the White Earth of a molar referable to this species. No doubt, therefore, that during these times the monkey family was present and chattered in the woodlands of eastern Nebraska during Miocene times.

Many additional species of mammals have been unearthed in the Miocene of Colorado which have not yet been found in the plains, but which no doubt flourished here at that time. The preceding animal forms, however, are only a small part of the species that have been found, and all of those found probably are only a small part of those that flourished during Miocene times. During the whole of this epoch, which, as has already been stated, evidently was of long duration, there was a most happy combination of physical geography and climate. Warm, temperate conditions existed almost to the poles. In Nebraska the magnificent savannas and

forests that covered the land gave shelter and food to countless numbers of the mammalia that here enjoyed a happy existence. The conditions were most favorable, not only to the perpetuation and development of animal forms, but for the evolution of species that were only to be developed completely during the following epoch.

Like the preceding epochs, the Miocene was destined to come to a close. The changing conditions evidently were not sudden—they were of such a gradual character as slowly to alter the environment of the animal life of the times. With change of climate came change of flora, which in turn changed or destroyed the rich and wonderful Miocene forms of animal life. The final catastrophe came at the close. It was one of the greatest revolutions that occurred in the history of the globe. At the end of the Jurassic, "the Sierras, which had been a marginal sea bottom, were crushed together and folded into a mountain range. This transferred the coast farther westward, and the present coast range became the marginal sea bottom, and received an abundance of sediment, until, in turn, at the end of the Miocene, it also yielded to the lateral pressure from the Pacific, and was raised up into the coast range."—(Le Conte). Coincident with this movement, great fissures were formed in the Cascade, and great floods of lava poured out, which in north California covered in wide sheets a great extent of country, several hundred feet thick. The lava flood in Oregon, in places, was 3,000 feet thick. It extended from Washington Territory to British Columbia. The area of this great flood of lava covered at least 80,000 square miles, a space much larger than the whole of Nebraska. Richthofen has shown (Natural History of Volcanic Rocks), that this great lava flood could not have proceeded from the dozen extinct craters that cover this region, and that therefore, as stated above, it must have proceeded from earth fractures or fissures. At the same time the Plateau region was farther elevated, the Miocene lakes were drained or shifted eastward, and the region of the plains was still more depressed. This sinking of the plains extended far to the south, almost to the gulf, and to the east in its central portion about to where Columbus is located, on the Union Pacific Railroad, and for an unknown distance to the north. On the Niobrara its eastern line was near the mouth of Keya Paha or Turtle Hill River. On the Republican, it was near the center of Harlan County. It thus changed the whole aspect

of the western half of the continent. To the life then on the globe it must have been an event so appalling that the overthrow of Pompeii and Herculaneum, and the great Lisbon earthquake, in comparison with it, would have been an insignificant event. The throes of this event must have shaken the globe and affected all life, vegetable and animal. And as a matter of fact, the entire facies of the animal life of the globe was changed from this time forward, as we shall presently see. Thus was closed the Miocene epoch.

CHAPTER VI.

TERTIARY PERIOD, CONTINUED.—PLIOCENE EPOCH.

Inauguration of the Pliocene.—Extent of the Pliocene Lake of the Plains.—Other Pliocene Lakes.—Eruptions at the beginning and during the Pliocene.—Thickness of the Pliocene Beds.—Erosion of the Pliocene Beds.—Elevation of the Pliocene Deposits.—Eastward Barrier of the Pliocene Lake of the Plains.—General Warren's Explanation.—Materials of the Pliocene Beds.—Sections from the Niobrara, Loup and Driftwood.—General Character in the Republican Valley.—So-called Tripoli Beds, and their Geyser Origin.—Their Chemical Composition.—Nebraska Once a Geyser Region.—Length of the Pliocene Epoch.—Vegetable Life.—Animal Life.—Rodents.—Horse Family.—Camel Family.—Bisons.—Bear Family.—Cat Family.—Dog Family.—Favorable Conditions during the Pliocene.—Picture of the Pliocene Epoch.—Close of the Pliocene.—Convulsive Movements further West.—Gradual Character of its Close.—General Remarks on the Tertiary Epochs.

AT THE close of the last chapter it was stated how the Miocene epoch came to a close. At the opening of the Pliocene epoch, the great Miocene lake of the plains underwent further subsidence, but gently and gradually. There is no trace on the plains of the intervention of a period of dry land, as some have supposed. The Miocene lake here became the Pliocene by subsidence and extension in every direction. It became much deeper than it had been. "On the west it now reached the foot-hills of the Colorado Range; on the south it enlarged the borders of the Miocene lake from southern Nebraska, through Kansas, the Indian Territory, far into Texas; on the north it stretched over the whole of the

plains into British America."—(King). The Pliocene, therefore, in eastern Nebraska, overlies the Cretaceous In south-west Nebraska it lies on the Fort Pierre Cretaceous. Further west, the disturbance, as already stated, were much greater at the close of the Miocene. There severe crumpling and fissuring of the earth's crust had taken place. The basin region subsided to such an extent that the Pliocene lake that was formed extended from the Wasatch to the Sierras, and northward to the Columbia, while its southward extension has not been ascertained. King believes that the ejection of trachytes occurred at the close of the Miocene, and that the ejection of rhyolites marks the beginning, in this region, of the Pliocene epoch. According to him, the basaltic eruptions occurred wholly within the Pliocene.* Still another Pliocene lake existed in North Park, (North Park Group of Hayden.) It only comes within the plan of this work to discuss the Pliocene lake deposits of the plains, which cover so large a portion of Nebraska. These deposits constitute the Loup Fork Group of Hayden, and the Niobrara of Marsh.

On the plains the Pliocene beds, wherever their point of junction could be observed, are conformable to the underlying Miocene. King, however, remarks that they are in places unconformable, which I have not observed. Often they shade so insensibly into each other that the line of junction could only be ascertained by the fossils which they entombed.

Thickness of the Pliocene Beds.—Along the foot-hills of the Colorado Range, the Pliocene beds average nearly 2,000 feet in thickness. They thin out eastward, probably because the mass of materials was obtained from the mountains, the greater part of which was precipitated along, or near its western shores. In Nebraska, Kansas, and Dakota towards the east, the Pliocene beds become thinner; until they run out entirely. It is certain, however, that originally they were much thicker than at present. Owing to them being the upper rocks at the time, they must have been subjected to an enormous amount of erosion during the subsequent Quaternary age. The monuments of this erosion are still visible in many places. In township 10 North and 26 West of 6th Meridian there is a Pliocene peak, nearly 300 feet high, that represents the original level of these deposits. In 13 North, 51 West, there are limestone cliffs 75 feet high, and similar ones all over this region in

*See King's Systematic Geology of the 40th Parallel.

far separated, isolated spots. The top of all these rocky cliffs, whose strata are horizontal, represent where the general level of the Pliocene once was. Perhaps the most remarkable monument of the original level of the Pliocene in Nebraska, is at Scott's Bluffs, and at Chimney Rock, on the North Platte. These have long been noted landmarks. The country is here eroded into many forms, exhibiting some of the peculiar natural architecture of the Bad Lands. Chimney Rock is about 150 feet high. The strata here and at Scott's Bluffs are horizontal, and therefore the general level of the country must have been as elevated, at least, as the top of these crags. No doubt much material has also been removed from the top of the highest of these old monuments, as they have been subjected to erosive agencies ever since the commencement of the Glacial Age. From two to four hundred feet, therefore, must have been removed from the general surface of the Pliocene deposits of the plains. Notwithstanding the immensity of this erosion, a considerable thickness of these deposits still remain. In Nebraska they range from 10 to 700 feet. King has remarked that at the mountains, where they are lofty and form powerful condensers of moisture, the resultant streams have carried away in front of them all the Tertiary and exposed the Cretaceous.

Elevation of the Pliocene.—At Chalk Bluffs, the line of separation between the Miocene and Pliocene is 6,000 feet above the sea level. Near 41° 30′ the Pliocene reaches an altitude of over 7,000 feet. In the valley of the Loup Fork the contact plane between the Miocene and Pliocene approximates to 3,000 feet. There is, therefore, a gradual sinking eastward of the contact plane between the Miocene and Pliocene.

Eastward Barrier of the Pliocene Lake—It has been a question what barriers on the east held in the waters of the Pliocene lake of the plains. Two theories have been suggested. One is that the whole western shore line, with the mountain chain against which it abuts, and the present incline towards the east, was low enough, during Pliocene times, to hold the waters of the lake. This theory, however, is irreconcilable with the known facts concerning the elevation of the Rocky Mountain system during the Tertiary epochs*. Evidently this region near the eastern shores of the lake, and on the south, was once elevated into a rim, and it was the sinking of this border, towards the close of the Pliocene, and the transference

*See Clarence King's Systematic Geology of the 40th Parallel, Chapter VI. on Stratigraphical Geology.

of the geosynclinal of the continent to the Missouri and Mississippi valleys, that helped to bring the Pliocene to a close. It is not at all impossible that future investigation will show that the present divide between the Missouri and the Mississippi was a portion of this rim, and that the Pliocene deposits that once covered eastern Nebraska were removed by erosion during subsequent glacial times. The Pliocene at least was deposited in a broad level lake between the Meridian of 98° and 105°, and subsequently this whole area of subsidence towards the east, accompanied by slight continued elevation towards the west, was transformed into an incline from the base of the foot-hills eastward. "From the 40th parallel region this dip of the Pliocene at present towards the east is equal to 4,000, and towards the south of 7,000 feet."—(King). The original discovery of the eastern conditions of the shore line of this old Pliocene lake of the plains was made by Lieutenant (now General) Warren, in the annual report of Captain (now General) Humphreys, for the year 1858. No clearer statements of this theory, and the reasons for it, have since been made. I announced the same theory in public lectures as early as 1872, and had adopted it without being aware that Warren had long anticipated me. Clarence King, also, by independent study, without knowing of Warren's discovery, had come to the same conclusion. I mention these facts to show that students of geology, in studying the phenomena of this region, will be forced to make this explanation. One curious feature of this subsidence of 4,000 feet eastward over the Pliocene region, is that no faults, breaks or crumplings have yet been detected. As the sediments of this old Pliocene lake are thickest next to the mountains, and thin out eastward, it is clear that the eastern rim was a low land, without lofty ridges or mountains. The streams that drained into it from that quarter were of insignificant size.

Materials of the Pliocene Beds of the Plains.—Near the mountains the materials of the Pliocene beds are exceedingly coarse, and where they are in contact with the foot-hills they are composed of conglomerates made up of water-worn pebbles, feldspar and quartz in masses, and some small pieces or chips of all the Archæan rocks which are represented towards the west. The fragments are of all sizes, from a shot to a man's head, and even larger. The coarser conglomerates form the upper beds, beneath which there are often much finer materials. The erosion of the upper strata has in many places cut through the coarse conglomerates and widened the bed below in the finer sediments, producing over-hanging rocks.

Beautiful illustrations of this kind of erosion can be seen along the streams flowing eastward from the Laramie Hills. South of the Union Pacific Railroad, west of Cheyenne, the Pliocene beds form irregular terraces, which often change or are prolonged into curious sharp escarpments. South of Cheyenne, and eastward, the upper beds are often made up of light, creamy limestone, sometimes exceedingly brittle, intercallated with small veins of chalcedony. Still further eastward, north and south of the Union Pacific Railroad, the Pliocene beds become arenaceous, but fine-grained, beds of clay and marl being interlaminated. The Chugwater is bordered for a long distance with abrupt cliffs of Pliocene rocks, often forming escarpments which have been cut out by lateral ravines and small canyons. At Scott's Bluffs, near the western line of Nebraska, there is a fine exposure of the Pliocene rocks, which are here made up of sandstones, marls and whitish and yellowish white clays. Along Lodge Pole Creek, the Pliocene rocks have assumed more the forms of bluffs. Here, and occasionally on the upper Republican, the thin, marly members sometimes contain thin masses of jasper-like rocks, which occasionally contain dendritic markings, produced by oxides of the metals. Among these, moss agates are occasionally found. On the Niobrara and Loup rivers there is, in many places, at the top, an immense amount of loose or at least incoherent sand, or loosely compacted sand. The decomposition of these Pliocene beds in these regions has produced the famous sand hills. Next below, are beds of compacted gravel and sand. Then come calcareous and arenaceous concretions, combined with or enclosed in whitish and yellowish grits. Greenish and greenish gray sand comes next. Arenaceous marl, shading from deep yellow to dull red, lies below the last. At the bottom is observed a grit of yellowish hue, often highly calcareous, and sometimes containing limestone more or less concretionary, from one to seven inches thick.

The following section, beginning at the top, I have taken about 75 miles above the mouth of the Keya Paha:

1.	Light brownish sand of undetermined thickness.	
2.	Incoherent gravel and sand	25 feet.
3.	Yellowish white grit, with calcareous concretions	19 "
4.	Greenish and grayish sand	27 "
5.	Reddish and yellowish sandy marl	35 "
6.	Yellowish gray calcareous grit, containing layers of concretionary limestone	42 "
	Total	148 "

The following is a section from the Loup, beginning at the top:

1.	Light brownish sand, of undetermined thickness.		
1.	Loosely compacted sand and pebbles	21	feet.
3.	Greenish and gray marls	13	"
4.	Concretionary limestone	17	"
5.	Sand and sandy marls	16	"
6.	Concretionary limestone	11	"
7.	Soft lime and marl	7	"
8.	Silicious limestone, with concretions of limestone containing iron and alumina	16	"
9.	Fine loose sandstone, only eight feet exposed	8	"
	Total	109	"

South of the Republican Valley, in Nebraska, on the Driftwood there are some fine exposures of the Pliocene. The following section, which I took in the spring of 1877, is from township 1 North and 32 West, and on sections 12 and 14. It is numbered from the top:

1.	Loosely compacted sand and pebbles, with ebb and flow structure	10	feet.
2.	Alternations of greenish and gray marls	14	"
3.	Soft concretionary limestone	8	"
4.	Sandy marl	10	"
5.	Soft concretionary limestone	6	"
6.	Soft limestone and marl	4	"
7.	Silicious limestone, with pockets and concretions of pure white lime	14	"
	Total	55	"

The strata in all these sections vary very much, even within a quarter of a mile, and sometimes within a hundred yards. The least variation is observed in the green marl beds. The section on the Driftwood, it will be observed, is quite different from the ones on the Loup and the Niobrara. On the south side of the Republican, in Harlan County, the Pliocene rests on the Niobrara Cretaceous, and so far as I could observe, conformably, Here the materials consist largely of lime mingled with silicious materials. Thick strata of marly silicious beds, and some beds of coarse, loosely compacted sandstones, intercallated with them alternate below. I regret that my section from this important locality has become illegible, and I only describe it from memory. From Harlan County to the west line of the State, along the Republican Valley, the rocky bluffs of the valley are made up of a silicious limestone, which often shades into a fine and then coarse conglomerate. The

Pliocene thins out towards the upper end of the valley, and near the State line, in places where it overlies the Fort Pierre Cretaceous, is only from twenty-five to sixty feet thick. The means at my disposal did not enable me to determine the probable cause of this phenomenon.

The most silicious strata of the Pliocene in Nebraska contain more or less of calcareous materials. The sandstones vary a great deal in texture, the finest, as elsewhere, being generally beneath, increasing in coarseness to the top, where, as already observed, the rocks often assume the character of fine pudding stone conglomerate. The pebbles, water-worn and smooth, are made up of all kinds of rock, metamorphic materials being the most abundant. Among these are granites, syenites, greenstones, quartz, sandstone and fragments of silicified wood. This conglomerate, when decomposed resembles the drift so closely that at first I mistook it for that formation. Above the mouth of the Arickeree, and at other points in southwestern Nebraska, the Pliocene is capped by an intensely hard silicious stratum, from two to ten feet thick. It varies from something akin to quartzite, to flint, hornstone and chalcedony. The color of the latter varies from a creamy white to transparent, and occasionally is coarsely opalized. A few moss agates are sometimes found in portions of this stratum. Prof. Mudge reports a similar stratum in the Pliocene near Fort Wallace, Kansas. Excepting this hard layer, much of even the most compact strata is apt to disintegrate on exposure to the elements. Sometimes the most compact portion is so irregular in structure as to interfere with the dressing of the stones for architectural purposes.

Polishing Powder.—Infusorial Earth.—Geyser Flocula.—One of the most remarkable of all the deposits of this Pliocene lake of the plains, is a peculiar, flour-like material that appears in beds of greater or less thickness and extent, that occurs on the Republican, the Loup, Niobrara, and other sections. When I first examined it under the microscope, eight years ago, a few diatoms were collected, from which circumstance it was regarded as probably of the character of tripoli. Since then, in many specimens that have come under my observation, a diatom has rarely been found. In almost every specimen examined, however, great numbers of the forms that Ehrenberg called Phytolitharia were detected. The most conspicuous of these are triangular in shape, with one edge convex and the other concave, or the opposite. They cover, under a micro-

scope magnifying 90,000 times, or 300 diameters, the space of about one-eighth of an inch, and of incalculable thinness. These specimens, under such high powers, are translucent. Many other curious microscopic forms occur. The chemical analysis of this earth, however, is very different from tripoli. It is proved to be a silicate of the alkaline earths, and most generally of soda, potash, magnesia or lime. Sometimes only one, and sometimes several of these alkalies are present. It ranges in color from light gray to snow white, green and yellowish. All these colors are sometimes found in the same bed, and the chemical composition varies even more than the color. To the touch it feels very much like flour. The best specimens have no grit, and when used as a polishing powder no scratches can be detected, even with the microscope. It is most abundant along the Republican, where it is found in almost every county. The following is a characteristic section, taken at a bed in Furnas County, south of the Republican, and about eight miles southeast of Arapahoe. It is exposed on the East half of Northeast of 8, and on West half of Northwest of 9, Township 3 North, and 21 West, of 6th Principal Meridian. One of these exposures here is near a quarter of a mile long. The measurements are from the top down:

SECTION.

1.	Loess, from three to	6
2.	Drift	3 feet.
3.	Compact silicate of lime and limestone	3 "
4.	Flour-like earth	12 "

This bed is made up of layers one-fourth of an inch in thickness, of snowy whiteness, and other layers, from nine inches to a foot thick, of a grayish white color. Nine feet from the top there is a layer two inches thick, of a greenish color, which contains potash and iron.

As already intimated, it polishes as successfully and as finely as the best tripoli.

Origin of this Flour-like Earth.—Near or in many of these beds all over the Pliocene region of the plains are found many extinct geyser tubes, and sometimes old geyser basins. Of these I observed at least thirty between Arapahoe and the west line of the State. I have also found them in the Loup region and on the Niobrara. As some of these geyser tubes had their exit in the Fort Pierre Group, on the upper Republican, it is probable that they

commenced their work in the Cretaceous period, and were in operation all through the long centuries of the Eocene, Miocene and Pliocene epochs, and far into the Quaternary. A similar bed exists on Oak Creek, which was deposited in interglacial times. Nebraska, and at least northern Kansas, in fact, was a great geyser region all through the Tertiary period. It far exceeded in the number and magnitude of its geysers the upper Yellowstone region and Iceland at the present day. Few memorials of these old extinct geysers are visible at the present time, owing to their being covered up by the superincumbent Quaternary deposits, but enough remain to show that a prodigious number must have existed in at least Pliocene times. It is probable that this flour-like silico alkaline earth owes its origin to these old geysers. It is well known that hot alkaline waters dissolve silica. When, therefore, the geyser streams holding silica and alkalies in solution was poured into this old lake, it was precipitated, on cooling, to the bottom. Indeed, many of the flakes of this earth, under the microscope, clearly resemble the dried flocculent flakes of aluminic silicate, which the chemist obtains by pouring soluble sodic silicate into a solution of sodic aluminate. Another fact which tends to establish the probability of this theory is that this Pliocene silico alkaline earth, on analyses, bears a striking resemblance to geyserite, which is obtained from the deposits of existing geysers. The following analysis are illustrations of this statement. No. 1 is an analysis of this earth from the deposit near Arapahoe; No. 2, from the Loup; No. 3, from Iceland, and No. 3, from the Yellowstone. No. 1 and 2 were made by myself; No. 3 was made by Forchhammar, and No. 4 by Dr. F. M. Endlich:

.	1	2	3	4
Loss on ignition......	....	....	....	8 00
Silica.................	67 01	80 17	84 43	76 80
Water..................	8 03	7 43	7 88	5 00
Alumina................	7 11	4 71	3 07	9 46
Iron...................	2 81	3 01	1 91	trace
Lime...................	2 01	92	0 70	1 80
Soda and potassa.....	7 87	2 27	92	trace
Magnesia.............	4 05	80	1 06	trace
	98 89	99 31	99 98	101 06

From these analyses it is evident that the principal difference between this Pliocene earth and geyserite is that the former contains a much larger per cent of alkalies; though the specimen from the Loup is strikingly like the geyserite from Iceland. By reference

to Dr. Endlich's report on the composition of the geyserites of the Yellowstone,* it will be seen that they differ very much in the per cent of their constituent elements. In the great number of analyses reported by him from as many different geysers, no two are alike. Often geysers only a few feet apart produce very different qualities of geyserite. The same is true of this peculiar earth under discusion. It not only differs a great deal in different localities, but even in different layers of the same stratum. It differs most in the quantity of the alkalies which it contains. Some specimens contain twenty or more per cent, while others contain only a trace, the latter approximating closely in chemical, though not in physical constitution, to the true geyserite. I submit whether these facts do not indicate a similar origin. It is possible that the peculiar modification of geyserite into a flour-like alkaline silicate may have resulted from geysers that were active in the waters of this old Pliocene lake.

The deposits of a similar character in the Quaternary contain, where I have chemically examined them, a larger per cent of iron, and are coarser in texture.

Length of the Pliocene Epoch.—The great amount of erosion to which the Pliocene rocks have been subjected, and the great thickness of the beds yet remaining, especially along the base of the mountains on the west, indicates that this epoch was of long duration. It probably endured through as many centuries as the preceding Miocene.

Life of the Pliocene Epoch.—Vegetation.—In the lower beds of the Nebraska Pliocene are found, in many places, and especially on the Niobrara, many remains of coniferous trees. Among these are petrified wood, cones and leaves. It is possible that some of the petrified wood may have been derived from older formations. If not, then there flourished during these times at least one araucarian pine. A flake from an agatized specimen which I obtained from the Niobrara, under the microscope gave distinctly the structure of the araucarians. There is no such doubt about the common pine family, as both cones and leaves of these are preserved. The giant trees (*Sequoias*) must have been abundant, judging from the number of their remains. One species of cedar, closely related to, if not identical with our common juniper, has also left its remains in the Pliocene of the Republican Valley. Along with the last, a cypress

*Hayden's Report for 1872, p. 157.

occurs. On the Niobrara, in the lower beds of the Pliocene, occur, at rare intervals, palm-like leaf remains, which probably belonged to some species of sabal, though the remains were too indistinct to identify. At the same horizon remains of fig leaves occur. There occur, also, occasional remains of the Sweet Fern (*Comptonia*), Sweet Gum, Locust (*Robinia*), Honey Locust (*Gleditschia*), Cassia, Sumach (*Rhus*), Walnut (*Juglans*), Tulip tree (*Liriodendron*), Staff tree (*Celastrus*), Cottonwoods (*Populus*), and Oaks. A petrified oak log, from the Niobrara Pliocene, in the cabinet of the State University, is remarkable for its beauty and the distinctness with which its structure has been preserved. The cells and medullary rays are as perfect as in a live oak of to-day. In Harlan County, on the south side of the Republican River, occur masses of silicious limestone that are filled with the petrified or semi-petrified seeds of probably some species of Arrow-wood (*Viburnam*), which is a member of our Honeysuckle family, which had its greatest development in Tertiary times. A flora similar to this characterized Europe during this epoch, but it disappeared at the end of the Tertiary. Here, however, our conspicuous vegetable forms are yet Tertiary in type, and almost in species. If Heer is correct, many of our existing American species abounded already in Greenland, Iceland and Spitzbergen in the middle Tertiary. So far, therefore, as our flora is concerned, America, as has long since been remarked, is the old world.

Animal Life.—The turtle family was probably represented by fewer species during the Pliocene than in the previous epoch. Those that I have observed myself in the Niobrara Pliocene were land tortoises, belonging to the genus Testudo. Their remains were mixed with those of mammals.

During this epoch the higher forms of vegetable life, and especially the mammalian type, had a remarkable development. They must have been exceedingly abundant around the shores of the great lake of the plains, as is evident from the vast numbers of their remains.

The birds were represented by an eagle (*Aquila Dananus*), and a ~~cormorant~~ (*Grus Haydeni*), both found on the Loup, and described by Marsh. The existence of the eagle implies the presence of other species. And there can be no question that the happy physical conditions of those times were favorable to a great development of bird life.

'Grus is crane

The rodents were represented by several species. Among these was a porcupine (*Hystrix venustus*), and a beaver (*Castor tortus*), about half the size of the one now living.

The horse family (*Equidæ*), were represented by at least four genera and fifteen species. One of the most remarkable of these genera was the Hipparian, which was already present in the previous Miocene, and was described under that head. The species were comparatively small in size. Hyperion occidentalis, whose remains occur at several horizons, and at widely separated localities, was the largest species, but was only about the size of the ass. Three other species, found on the Niobrara, and described by Leidy, were still smaller. Merychippus, another genus, which occurs on the Niobrara, was so named because of its large, broad grinders. The name means ruminating horse, but it refers only to the resemblance, as it did not partake of the character of ruminants. Merychippus mirabilis, the largest of the two species described by Leidy, was a little larger than the ass. Protohippus, which is also represented in the Nebraska Pliocene by at least four species, had even a more complicated structure of the enamel of the teeth than the modern horse. Protohippus supremus, which in size was about half way between the ass and horse, was the largest species. Protohippus parvulus, which was obtained by Marsh at Antelope Station, Nebraska, was only about two and a half feet high when mature. Closely related to the preceding was Pliohippus, of which Marsh described two species. It had only one hoof to each foot, but large splint bones still remained. Its principal points of difference from the true horse lay in the shape of the skull, hoof, and in the shorter molars. Another genus of animals from the Niobrara, supposed to belong to the horse family, but which reference is uncertain, owing to the paucity of the materials for determination, Leidy has called Hyohippus, and under that name has described two species. The most perfect, at the least the most modern of the Pliocene horses of Nebraska, was Equus excelsus. Dr. Hayden first found its remains on the Loup, then on the Niobrara, and then at other points. It was about the size of a medium-sized modern horse, and differed only in trifling details from the present one. I have found its remains in the uppermost Pliocene beds in the Republican Valley, and in the Quaternary. It extended over from the Pliocene to interglacial times. This most modern of the Pliocene horses, seems to have been the culminating form of the family

in this epoch. It will be remembered that the family was first represented in the Eocene of the mountains by the Dawn Horse, or Eohippus, with five toes on the fore feet. The horses abounded all through the Miocene and Pliocene, when in the higher forms in this latter epoch the toes had all, except the middle one, disappeared, but leaving as a memorial of their former presence the splint bones. It is evident that they must have existed here in Pliocene times in prodigious numbers. In fact, these regions, above any other in any geological age, were dominated by horses.

One species of Rhinoceros was a contemporary of the Pliocene horses. It was about the size of the Indian Rhinoceros, and its teeth had the same formula. Leidy has named it R. crassus.

The elephant family (*Proboscidians*), which first became sharply outlined in the preceding Miocene epoch, was represented in the Nebraska Pliocene by at least two genera and species. Mastodon mirificus (wonderful Mastodon), was first described by Leidy from the Pliocene beds on the Loup. Hayden also found its remains in abundance on the Niobrara. I have also observed them on the Driftwood, and in other localities. The finest molar of this animal that I have seen is in the possession of Captain Palmer, in Plattsmouth, who obtained it from the Republican Valley. It is finely agatized, and is remarkable for its beauty. It is fortunate for us that it fell into the hands of a gentleman who will retain it in the State. This species of Mastodon belongs to Falconer's subgenus Tetralophodon. Leidy was uncertain whether it had tusks. A badly decayed section of a skull which I found on the Driftwood, and which unfortunately fell to pieces in taking it out, had a section of one tusk left. It is my own conviction that it had tusks in both jaws. This species has not yet been found elsewhere outside of Nebraska.

The remains of a gigantic elephant (*Elephas imperator*) was also found by Hayden on the Niobrara, and described by Leidy. It was either distinct from the elephant that appeared afterwards during the Quaternary, or else was of larger size. A portion of the femur of what I take to be this species, now in the cabinet of the University, is certainly more robust in form than that of the Quaternary elephants. The remains of other species have been found on the Niobrara and Loup, but have not yet been specifically described. It is evi lent, therefore, that in Pliocene times elephants and mastodons were abundant over the land surface of Nebraska.

That old type of mammals, so common in Eocene times, but now confined to South America, the Tapirs were represented in the Pliocene of the plains by one species. Marsh, who describes it, calls it Tapirus rarus.

The hog family (*Suidæ*) had fewer representatives than in the preceding epoch. One species of peccary alone seems to have been abundant.

Ruminants were abundant during the Pliocene in Nebraska. An antelope, (*Cosoryx furcatus*,) described by Leidy, and intermediate in character between the deers and antelopes, has left its remains on the Niobrara. In company with the last was a true deer (*Cervus Warreni*), also described by Leidy. It was about the size of the Virginia deer.

The Oreodons, described under the Miocene, had dwindled in the Pliocene to three species of the genus Merychyus. The relative position, form of the teeth, and their number was the same as in Oreodon. The crowns of the teeth, however, were larger in proportion to their breadth than in Oreodon. Merychyus major was the largest species, and was near the size of the camel. M. medius was intermediate in size between the llama and camel. On the whole, while the number of species was less, the average size was greater in this family than during the Miocene.

The camel family (*Camelidæ*) were even richer in genera, species, and the number of individuals than during the Miocene. The most characteristic genus was Procamelus, which was represented by at least four species, three of which were described by Leidy. Their remains are found on the Niobrara, Loup, and Republican. Procamelus had one more premolar to the upper, and two more to the lower series of teeth than in the modern camel. This indicated a less mature condition, or a condition before they have shed those teeth which reduce them to that observed in their adult form. The lower true molars are also smaller in proportion to the size of the jaw than is the existing camel. The molar series, though composed of smaller teeth than in the camel, occupy, because of their greater number, more space along the border of the jaw. Thus in the camel, while the four molar teeth occupy five and a half inches, in in Procamelus robustus the six molars occupy six and a fourth inches.—(Leidy.) Some of the species approximate in some of the characters of the lower jaw to the llamas. Procamelus robustus, the largest species, was about the size of the existing camel. The

remains of P. occidentalis, which was about two-thirds as large, are the most abundant. P. gracilis, a still smaller species, was about as large as a sheep. I have found the remains of another species most nearly related to P. robustus, and if it proves to be distinct, will call it P. Nebraskensis. Another species, whose remains Hayden found on the Niobrara, Leidy has called Homocamelus caninus. It was remarkable, among other things, for the narrow snout-like prolongation of the fore part of the face. The palate was more deeply vaulted than in the camel. The caniniform incisor, the canine and first premolar were all separated from each other, and from the succeeding continuous row of premolars, and true molars by wide arching intervals. The largest of all the family, whose remains were found, Leidy has named Megalomeryx Niobrarensis, from the locality where its remains were obtained. The molar teeth had affinities to those of the llama and sheep. It was probably about one-fourth larger than the modern camel. A still more curious, comprehensive, camel-like animal, described by Leidy, was Merycodus necatus. Its molar teeth combined the characters found in the sheep, camel, and deer. It was about as large as the latter animal.

Bisons already existed in the Pliocene epoch in Nebraska. The progenitors of our buffalo probably then existed in the forms which Marsh has described under the names of Bison ferox and Bison Alleni.

A species which Leidy has described, under the name of Leptarctus primus, was a bear-like animal, closely allied to, and about the size of the existing Coati of South America.

The cat family (*Feüdæ*) had fewer representatives than in the preceding Miocene. Ælurodon ferox was slightly larger than the largest American wolves. One of its sectorial molars, according to Leidy, was intermediate in character between that of the wolves and the cats. "It approached in size the similar molar of a small Bengal tiger. It had the proportion of the similar molar of the wolves, and in addition the anterior accessory lobe of the cats."—(Leidy.) The most characteristic, however, of these cats of the Pliocene, was Pseudælurus intrepidus. The first species was found and described from the Miocene of France by M. Gervais. It was somewhat remarkable that another species should be found in the Pliocene of Nebraska. The jaw of this species was intermediate in character between that of the panther and lynx. The jaws and

teeth were much as in the cat family generally, but in minute details they resembled most nearly those of the lynx.

The dog family (*Canidæ*) was much more fully represented than the last, not less than four species having already been described by Leidy. Canis Haydeni was a wolf of much larger size and more robust form than any now in existence. Another species was also slightly larger than any now living. Leidy calls it Canis rarus, and considers it a near relative if not actual projenitor of our present wolf (*Canis occidentalis*). Cotemporary with these large species, and inhabiting the same localities, were two of small size. One of these, called Canis temerarius, was intermediate in form between our prairie wolf and red fox. A still smaller species, more fox than wolf, was about the size of the swift (*Canis velox*).

From the preceding it is apparent that many forms of mammalian life culminated in the number of species and the size of individuals during the Pliocene epoch. The conditions during those times must have been exceedingly favorable to the development of mammalian life. Not the least remarkable is it that most of those animal forms which are now regarded as most useful to man were the most numerous and best represented during an epoch when, so far as we now certainly know, he had not become an actor on the stage of the world. At least no undoubted monuments of his presence in the world during Pliocene times have been preserved in geological history or tradition. The alleged special servants of man, however, were present during the Pliocene epoch in extraordinary numbers. Even the mastodon might have been made as serviceable as the elephant was in historic times. There is no good reason to doubt that the great Niobrara elephant (*E. imperator*) might have been trained to toil as successfully as the species now living in Asia and Africa. Some of the great number of species of the camel family could certainly have been made as useful as the modern "ship of the desert" Even the horse family culminated during those times in the number of species. The fifteen species already described from the Pliocene, were probably only a small fraction of the kinds that then existed. If the three-toed Hyperion horses were not adapted to the service of man, some of the many species of Protohippus and Equus certainly could have been utilized. We may, therefore, abandon the idea that the development of animal life was designed by the Supreme Intelligence solely for the gratification and use of man. This may have been one pur-

pose, but, in the nature of the case, it could only have been one out of many conceivable purposes.

Let us now, if we can, form some picture of the character and physical condition of the Tertiary ages. Take, for example, the middle Pliocene. Had we been in existence then, and started westward on a journey from some point near where the Missouri now flows, much of the peculiar life of the times would have been observed. The climate was congenial in an eminent degree. The great Pliocene lake caused a much moisture atmosphere than exists at present. Groves of Sequoias, like the present gigantic trees of California, the glyptostrobus of China and Japan, the cypress, the date and the palm, were interpersed with magnificent savannas. The songs of ten thousand birds, many of them of the most beautiful plumage, would have greeted our ears. At some places, herds of thousands of Oreodons would have been encountered. Bisons, similar in form to our buffaloes, would have been seen cropping the grass. At other points might have been seen herds of elephants and mastodons quietly proceeding towards some streamlet, or lakelet, to indulge in a bath. Vast numbers of many species of camels would have been seen reposing at mid-day on a gentle hill-side under the shade of sequoias or cypress. More curious than all, thousands of Hyperions, those wonderful three-toed horses, along with many kinds of one-toed horses, of all sizes, would sometimes have made the earth tremble under their tread. When, at last, in such a westward journey, the shores of the great Pliocene lake would be reached, its borders would have been a marvel for the life represented there. A rhinoceros might have been seen wallowing in the mud near the shore. Thousands of water-fowl would have been riding the gentle waves. Elephants, camels, oredons, and horses might have been seen there slaking their thirst in the streamlets flowing into the lake. Life would have been observed everywhere—the hum of insects and the song of birds in the air—life in the trees, in forest and glade, on land and lake Most of it, too, was happy life. It is true some unfortunate ruminants would fall victims to the gigantic wolves and cats of the time, but the carnivora were not the rulers of the land. Grass and leaf, and seed, and fruit-eating animals, were the rulers of the Pliocene world in central North America. It was a physical paradise, for violence, rapine, and murder, were the exception and not the rule Violence, indeed, has existed in every geological age, but in Plio-

cene America, herbivorous life was so dominant that it could successfully defend itself against the carnivora, and the latter evidently obtained most of their prey by stealth and by picking off the aged and infirm. Animal life is generally happy when it is left alone, and this was specially the case during American Pliocene times. It is a grave reflection on humanity that, not the Creator, but man's injustice and inhumanity, produces most of the misery which we see in the world. This is, however, but a very faint picture of these happy Pliocene times which lasted for untold ages. But every one can, for himself, by "the aid of the scientific imagination," form such pictures of the wonders of that old-time world.

Close of the Pliocene Epoch.—There is evidence that the Pliocene epoch only gradually came to a close. The lake of the plains was probably partially drained, and a large part of its surface became dry land long before the last centuries of the Pliocene had ended. Clarence King describes a series "of coarse semi-stratified gravels and conglomerates" along the eastern base of the Colorado Range, which, "in the benches of the Sybille, distinctly overlie the Niobrara Pliocene, which abut against the Archaean core of the range," from which these materials were derived. The same formations are found at the head of the Chugwater, the valley of the Big Thompson, and at other points. In places on these streams, these gravels are from 200 to 300 feet thick, and descend in rude terraces. As these formations, according to King, overlie the Niobrara Pliocene, and antedate the Quarternary, they evidently constitute the closing deposits of the Pliocene epoch. I have detected the equivalents of these deposits nowhere in Nebraska, even where it is least eroded. It is probable, therefore, that the great lake of the plains was drained before these deposits were laid down. The eastern border of the great Pliocene rim commenced to descend and gradually left out the water until much of this great lake of the plains became dry land. There is also evidence of increasing cold in the deposits of this lake through their upper sections. The southern shores of the lake were probably rising at the same time, which would help to intensify the growing cold. An ice cap had now formed in polar regions, and conditions of climate similar to the present intervened. Age after age the increasing cold, accompanied by gradual elevation of land towards the north, continued, until finally the Arctic ice cap crept down to our present temperate latitudes. The flora and fauna of the Pliocene migrated southward,

and many species and genera were exterminated. The distinct fauna that made its appearance during the Quaternary originated some time during this transformation of the Pliocene into the glacial epoch.

During the closing centuries of the Pliocene epoch, some convulsive movements occurred further west. King remarks "that the whole country from about 114° 30′ was depressed to the west, the western edge of the Pliocene lake settling 2,000 feet." * * * "The same is true from Thousand Spring Valley eastward to Cache Valley, and to the base of the Wasatch, which is a region of recurrent faults." * * "I consider it proved that the displacement at the eastern base of the Sierras, and the western base of the Wasatch, occurred at the close of the Pliocene, and thus broke the one broad lacustrine basin into two new lake basins—one at the foot of the Sierras, the other under the shadow of the Wasatch Range—which were to receive the waters of the quaternal age." Thus it appears that as the Miocene closed with the production of fractures and fissures that covered a vast area with lava, so the closing centuries of the Pliocene were characterized by great vertical displacements of mountain chains.

General Remarks on the Tertiary.—Many of the strata of the Miocene deposits were specially favorable for the preservation of animal remains. Some of the strata of the Pliocene, in at least a few localities, were scarcely less adapted to such a purpose. The perfect petrifaction of many of these remains also indicates that this property was possessed by these waters in an eminent degree. The mammalian skeletons must have been carried into the old lakes during flood time from some of the low lands that were subjected to overflow, and once in the quiet, muddy bottom of the lake, were soon covered by sediments that preserved them to our times. The very original sharpness of the outline of these remains have been preserved. Seldom are any marks of erosion detected on any of the specimens. The curious feature about these remains is that few representatives of any sub-kingdom of animals, except the vertebrates, have been preserved, and of these no classes but mammals and birds, except a few species of turtles. No fishes have yet been found, and only a few mollusks, and these, except a land snail, of comparatively low type. Fish and mollusks could not have existed extensively in these lakes, or else their remains would have been preserved. The climate certainly was favorable to amphibious

mammals, but none, except the marsh-loving beaver and rhinoceros have yet been found. Leidy has suggested that the explanation might be found in the probability that these old lakes were occasionally flooded by the sea, producing an alternation of salt, brackish and fresh water conditions. If that had been the case, it appears to me that some indications of destroyed marine life would have been detected. I suggest that the explanation may be found in the probability that the waters of these lakes were too alkaline to be favorable to life. The deposits from these lakes indicate an excessively alkaline condition of the water. They are rarely found free from the alkaline earths, and many of the strata are almost wholly composed of them. Thick beds of almost pure marl abound—not marl produced by beds of shells, but by precipitation from water supersaturated at certain times with alkaline matters. Such waters certainly were most unfavorable to animal life, and accounts for the paucity of fresh water remains.

CHAPTER VII.

QUATERNARY AGE.—GLACIAL PERIOD TO THE LOESS.—SUPERFICIAL DEPOSITS.

Opening of the Glacial Period.—A period of great humidity and cold.—Glaciation of the Plains.—Direction of the Glacial Mass and thickness.—Materials.—Blue Clay, its extent and character.—Resemblance to the Till and Erie Clays.—Analysis.—Whitish Clays.—Boulder Clay.—Drift Materials.—Description of a Section.—Old Forest Bed.—Extent, Character and Sections—Its Fossils—Second Appearance of Glacial Drift.—Kames.—Calcareous and Silicious Materials.—Section of them and General Character.—Transition Beds—Analysis of the Calcareous Materials.—Origin of these Beds.—Course of events to the beginning of the Loess.

WE have seen at the close of the last chapter how the Pliocene epoch closed its remarkable history. Its closing centuries were the opening ones of the Quaternary Age. The continent had sunken towards the south and was rising towards the north. Where once had been the floor of a lake of the plains had now supervened a very great change of level. The southern end of the once great Pliocene lake was now, at least, at the level of the sea, and the northern end was 7,000 feet higher. The plains were dessicated before the Pliocene had entirely passed away. King has given reasons to suppose that this was even the case with the great lake of the basin region—that between the Pliocene and Quaternary this region was dried up. Following this condition of dryness was one of great humidity and a much lower temperature than the present. The snows of winter accumulated too rapidly finally to be removed by the summer warmth. Eventually the plains of Nebraska became glaciated and were covered by a thick mantle of ice. This was the first, or glacial period of the Quaternary. In this respect Nebraska agrees with the Quaternary in eastern America, where Dana divides the age into the Glacial period, the Champlain or low level period, and the Terrace or recent period. These divisions are not strictly applicable to Nebraska. Here we have a Glacial, a Boulder Clay, or true Drift, a Forest Bed, a second Drift, Loess and Terrace period. These divisions are more or less clearly outlined in our superficial geology.

Glacial Period.

The monuments of this period are undoubted. Along the Missouri River, from Fort Calhoun to the Kansas line, wherever the superficial deposits are removed and hard limestones constitute the surface rocks, they are worn as smooth as mirrors, except diamond-like scratches which cross them in a direction averaging about 17 degrees east of south. Below Plattsmouth at one point they run 27 degrees east of south. On the Platte, as far west as the limestone extends, the direction east of south averages about 19 degrees. At Stout's former stone quarry, twelve miles southeast of Lincoln, the direction is 13½ degrees east of south. These markings at this quarry seem to cross fainter lines whose direction was a little more easterly. In other places these slightly divergent lines are found, as if the ice in glacial times had moved at first more easterly than it did later. Where the rocks are of a soft, yielding nature, as in the Cretaceous and Tertiary these lines have long since been effaced. That they once existed is more than probable. On the Niobrara at a few points where a hard, silicious layer of Cretaceous rocks but recently was exposed to the surface, faint glacial lines were visible. As such markings are now made by existing glaciers, all geologists refer these scratches to a similar origin.

The materials lying on the country rock over the greater part of the State are additional evidences of the former presence of glaciers on our plains. The following section, taken on Oak Creek, Lancaster County, shows the character of the materials laid down during this age. The section begins at the top.

1.	Black surface soil	4 feet.
2.	Loess	21 "
3.	Calcareous sand	7 "
4.	Gravel, sand and drift boulders	5 "
5.	Black soil, with silicified wood	2 "
6.	Gravel and boulders	4 "
7.	Modified drift-gravel and clay	9 "
8.	Blue clay	17 "
		69 feet.

Farther up the valley of Oak Creek a bed of blue clay exhibited the following characters. It lies on the deposits of the Dakota Group.

1.	Blue clay	5 feet.
2.	Sand	1 "
3.	Blue clay	13 "
4.	Fine sand and gravel	½ "
5.	Blue clay	11 "
		30½ feet.

Often, though not always, this blue clay has intercallated between its layers these thin strata of sand and pebbles. In Saline County where they occur the clay sometimes shades into sand and emerges from it the same way. This clay is a characteristic feature of the earliest deposits of the Quaternary over the greater part of southern Nebraska and over a considerable section of north Nebraska. In south Nebraska it occurs in at least three-fourths of the counties. It is brought to light more frequently in boring for water, but occasionally it also crops out in railroad cuts, ravines and small canyons. Its thickness ranges all the way from five to sixty feet. Where free from mechanical admixture of sand, it is exceedingly compact and hard. An augur penetrates it with great difficulty, and in such cases it almost bids defiance to a pick. Occasionally it is full of pebbles, many of which lie lengthwise the direction of the glacial path, and, like the underlying rock, are marked by parallel striæa. At other places, instead of pebbles and small boulders, it is intermixed with sand in greater or less quantity. In such places it readily permits of the passage of water, but where pure it is impervious. In most of these characters it bears a striking resemblance to the English till.* This till Geike shows was first formed beneath glacial ice (*Moraine Profunde*). A body of ice 3,000 feet thick moving forward a few inches or feet in a day would crush and pulverize everything beneath it. This thickness, at least of the glacial mass, can be inferred from the depth of the ice mass in the east, where valleys 5,000 feet deep were filled, as is known by the scorings that crossed them and were made at that height on the bounding mountains. Boulders are also known to have been carried across equally elevated mountains. It was nature's mighty millstone to reduce to powder the stony fragments and organic materials beneath it. On the final retreat of the glaciers this fine, impalpable mud in part accumulated at the lower end, and in part was carried away by the rushing streams to be deposited in quiet waters. In some such way it became somewhat irregularly laid down over the land. The Erie clays described on the north side of Lake Erie by Sir W. Logan had, according to Newberry, who studied them so thoroughly in Ohio, a similar origin. All such clays, according to these eminent authorities, owe their character, physical and chemical, directly or indirectly to glacial action. In Ohio Newberry, however, regards the Erie clays as a result of the

*See "The Great Ice Age," by James Geike.

flooding that followed immediately the first retreat of the glaciers. In Nebraska, however, they must have been formed at first beneath a glacial mass and then modified only in part by the floods that followed immediately on their retreat. The reason of this opinion is that here I have frequently found the boulders imbedded n the blue clay lying lengthwise of the path of the glacier, and striated like the rock beneath as already stated. If this clay had been deposited from water this peculiar distribution and position of the boulders would have been impossible.

The following analysis indicates the character of this blue clay. For purposes of comparison, I give also Wormly's analysis of the blue clay of Ohio:*

	Nebraska blue clay.	*Ohio blue clay.*
Water	3 70	4 00
Silicic Acid	61 80	59 70
Alumina	13 90	14 80
Iron Sesquioxide	5 01	4 60
Lime Carbonate	9 11	8 90
Magnesia	1 70	5 14
Fixed Alkalies	4 01	3 40
Loss in analysis	77	
	100 00	100 54

The character, as will be observed, of these clays, though so widely separated, closely resemble each other. It should, however, be remembered that other specimens are widely different—some having more silicic acid, alkalies, iron or alumina.

Above the blue clay, in a few places, a whitish clay occurs. I have not ascertained what relation it sustains to the blue clay, or what its chemical composition is.

Above these clays or till beds of boulder clay occur that occasionally exhibit true marks of stratification. Following this is ordinary drift material, which lies directly on the country rocks, where the blue, white and boulder clays are absent, as often occurs, especially in north Nebraska. This drift material is the most widely diffused geological deposit in the State, though in vertical thickness it is much less than others. Sometimes, in a few townships of some counties, it constitutes the surface soil, but generally it is buried beneath later deposits. In rare instances it seems to have been removed from the uplands by denudation, before the Loess was formed.

*Vol. I. of Newberry's Geological Survey of Ohio, page 177.

Sometimes, where it is exposed at the surface, it is so mingled with the Loess, Alluvium, and organic matter as to escape the attention of any one save a practical geologist. It ranges in thickness from a few inches to seventy-five feet. It may be much thicker, but if so I have seen no exposures that indicate it. Nowhere does it come to the surface over wide areas. In the northern part of the State it occasionally constitutes the surface, in the southern part of Dixon County, in the northern part of Wayne, and in portions of Cedar, Knox, Pierce, Antelope, and Holt counties. In townships 30 and and 31 north, range 1 and 2 east, in Cedar County, semicircular rows of Drift pebbles and boulders even yet extend across narrow valleys, that lie on the flanks of high bluffs in the form of terminal moraines of glaciers, the marks of which unnumbered centuries have not been able to efface. In this region some of the glacier-marked boulders are of great size, weighing many tons. One of the most remarkable lies near the quarter-section stone, between sections 25 and 36, in township 30 north, range 1 east. It lies on top of the highest bluff in this region, from which there is a magnificent view of the whole country around. It is a granitic quartzose rock, about four feet square. On the level top-surface there is a beautiful engraving of a child's foot, a half-moon, a grape-vine, and other hieroglyphics. The engraving of the child's foot is cut in its deepest part, three-fourths of an inch into the hardest rock, and for fidelity to nature it would do honor to the work of a Greek artist. Previous to my discovery of this relic of the past (1869), no one in that region had heard of its existence. It may have been the work of the mound-builders, as their peculiar pottery and mounds are found near by, but what implements enabled them to carve these symbols in this hard rock, as well as the purpose of such a monument, at such a place, will probably always remain a mystery.

South of the Platte the Drift creeps to the surface on some of the hillsides of Lancaster, Saunders, Saline, Butler, Gage, Seward, Johnson, Pawnee, and Jefferson counties. In fact, there are few counties in the eastern part of the State where the Drift is not occasionally exposed by denudation. Four miles northwest of Nebraska City, on the farm of Hon. J. F. Kinney, is a granitic boulder as large as a small house, on whose top smooth holes have been worn by the Indians in grinding or pounding corn. This boulder is imbedded in a Loess deposit, through which it extends from the

Drift below. Here, as in most other regions, the Drift varies a great deal in character. As already intimated, it has here been so modified by subsequent lacustrine agencies as generally to be capable of high cultivation. Recently I have made a special examination of the modified Drift in Johnson County. Where the ground was covered with pebbles, the spade showed that the soil beneath was composed largely of Loess materials, mixed with Drift sand and clay, and organic matter. Here it is often in layers, showing that it is genuine modified Drift. This modified Drift soil, during the last season, where it was well cultivated, yielded sixty bushels of corn to the acre. It is only inferior, if inferior at all, to the Loess, which will be considered in the next section. Where this Drift is the purest, it is composed of boulders, some of which are of large size, pebbles, gravel, sand, and a small per cent of alumina. In places the Drift contains considerable lime, which was, no doubt, produced by the disintegration during glacial times of the Niobrara division of Cretaceous rocks. Sometimes fragments of these Cretaceous rocks are found in the Drift. Generally the pebbles and boulders are composed of the primary rocks, such as quartz, quartzose, granite, greenstone, syenite, gneiss, porphyry, actinolite, etc. Occasionally the year presence of the Drift is indicated by large boulders sticking up through soil composed of very different material. In such cases I have learned by experience to look for the modified Drift, which is so valuable in the agriculture of this State. In the few localities where all the finer matter has been removed by water agency, numbers of the different forms of variegated agates, carnelians, jaspars, sardonyx, onyx, opals and petrified wood, etc., are found. Agates and petrified wood are specially abundant. The latter is found almost in every exposure of the Drift. Some of the agates vie in beauty with those obtained from the most celebrated localities in the mountains. Judging from the remains of the matrix still attached to some of them, they were originally formed in the secondary rocks, from which they were separated by the disintegration to which they were subjected by the wear and tear of the elements in glacial times.

A brief description of a remarkable section through the Drift on Oak Creek, Lancaster County, will not be out of place. A few miles from Lincoln the terrace on this creek, composed of Loess materials, approaches the creek very closely. In this well the Loess deposit was fifteen feet in thickness, then came two feet of

Drift, then two feet of compact peat, then clay and black soil, and then Drift and blue clay again. The lower Drift here probably represents the period of the first glacial advance. The upper clay, black soil, and peat represent the middle period when the glaciers had retreated and a new forest-bed covered the State. The Drift, immediately on top of this, marks the second advance of the glaciers. The Loess on top represents the final retreat of the glaciers, and that era of depression of the surface of the State when the greater part of it constituted a great fresh-water lake into which the Missouri, the Platte and the Republican rivers poured their waters.

Old Forest Bed.—This is not observed in sections through the Quaternary in all parts of the State. Sometimes it is apparently absent from whole counties, and probably its removal was caused by a second advance of the glaciers, to be considered presently. In some of the canyons of the Loup region I have found the bed of black soil, but without a vestige of silicified wood. In other sections of the same region it was sparingly present. It is possible that this may have been occasioned by a condition slightly resembling the present—that is, a condition of alternating forests and prairies. Though it is evident that the proportion of forest to prairie must have been much greater than at present, as east of the 99th meridian in 30 sections that I have examined through the Old Forest Bed, twenty-three contained silicified wood. West of the 99th meridian only three out of fifteen sections contained any. The following is a section in a canyon running into the West Loup, where no wood was visible. I examined the exposure carefully for half a mile, and the most dilligent search failed to bring any to light:

Surface soil	3	feet.
Loess	21	"
Calcareous sand and gravel	7	"
Boulders, flint and gravel	4	"
Carbonaceous, shaly clay	3	"
Black soil	4	"
Silicious clay	2	"
Gravel and boulders, exposed	3	"

The black soil of the Old Forest Bed in color and constitution closely resembles the black surface soils of the State at the present time. This is particularly true of the lower half. The upper portion has probably been so modified by subsequent glacial and water agencies as no longer to exhibit its original character. As already observed in the eastern part of the State, specially large quantities

of silicified wood are found in this Old Forest Bed. Of fifty specimens that I examined microscopically at different times, thirty-nine were conifers. A few oaks, a willow, a cottonwood and some other species that I could not determine also occurred among them. If these specimens are any indication of dominant type, then a coniferous vegetation flourished here during those times. Here are also found the remains of the elephant, mastodon, the Bison latifrons, a huge elk and deer, and the giant beaver (*Castor Ohiaticus*). Curiously enough, I found the molar of a horse in this same bed, but too much injured to identify specifically. An abundant animal life, a life remarkable for its gigantic character, ruled in these old forests. It was probably colder than at present in the same latitudes, but with conditions of moisture and temperature eminently adapted to the production of vast and sombre forests, whose solitudes were enlivened principally by huge herbivorous and carnivorous mammals. That the Forest Bed period was a long one is clear from the thickness of the bed that was formed, from its vast forests and the remains of its abounding animal life. Black soils form with excessive slowness, and as the Forest Bed is known, even in Nebraska, to have a thickness in places of ten feet, the time involved in its production is simply incalculable.

Second Appearance of Glacial Drift.—On top of the Old Forest bed materials, and where these have been removed, on top of the silicious clay floor of the Forest Bed, occur gravel, sands of various degrees of fineness, boulders and boulder clay. In places the boulders of various sizes constitute the principal portion of the overlying materials. Sometimes these boulders are marked with parallel striæ, and beds and piles of them occur of enormous thickness. One such exists on the banks of Oak Creek, six miles from Lincoln. Here I measured seventeen feet of vertical thickness of these boulders of all sizes, from a grain of corn to a hundred pounds in weight—some rounded and some angular, with sand also intermingled. In the upper portion of these beds there are signs, with greater or less distinctness, of stratification. Often it bears in its lower portions a striking resemblance to the drift materials below the Forest Beds. Above the indistinctly stratified materials are various beds in places where the stratification is undoubted. These beds are mostly made up of variously colored gravels and sands, the latter predominating.

Kames.—On the Logan, Elkhorn, on tributaries of the Republican and Loup, and in other places occur long rows of sometimes

gravels and sometimes sands, very distinct from the Pliocene sands of the Niobrara. The Loess deposits to be described hereafter abut against them, but often their tops have been blown over the Loess to such an extent that even geologists have been deceived into the belief that they are of very recent origin. They, however, antedate the Loess, as is evident from the fact that they extend beneath the latter. I am not sure whether any of them exhibit any true marks of stratification. They bear some resemblance to the Kames of Scotland and Asars of Scandinavia, and to them they are for the present referred, though doubtfully. Though their upper portions are composed of sands, they often shade down into fine and then coarse gravels. This is specially true in southwest Nebraska, where at long intervals canyons are found which partially cut through them.

Calcareous and Silicious Materials.—Between the deposits which are doubtfully referred to the Kames, and lying on their flanks, occur, in many places, great beds of fine silicious matter, which in places is calcareous to a greater or less degree, and is especially rich in iron, mostly in the form of a sesquioxide. It is often mistaken for Loess, whose character it often approaches. The best examples of it are seen in the Republican Valley, from Harlan County westward, where the line of junction between it and the overlying Loess is sharply outlined, and is exposed for thirty miles. Its color is a darker reddish brown than Loess. Under the microscope, the silicious materials appear coarser than the Loess, with the addition, occasionally, of small water-worn pebbles. It also varies much more in character. The following analysis, only partially completed, indicates its chemical character:

Insoluble (silicious) matter	78.10
Ferric oxide	5.98
Alumina	2.70
Lime carbonate	11.01
Lime phosphate, undetermined.	
Magnesia carbonate, "	
Potassa, "	
Soda, "	

At other points in Nebraska this reddish brown silicious matter shades insensibly into the overlying Loess. Such examples can be seen along the Missouri River from Plattsmouth to the south line of the State. Along this same route beds of almost pure sand oc-

casionally take its place. There are a few such points between La Platte and Omaha. Not unfrequently this deposit is highly calcareous in its lower and upper portion. When it gradually shades down into gravel and boulder beds, the latter are often covered by incrustrations of calcareous and other alkaline matter. It is possible that the alkaline matter that has been leached out of the overlying beds was deposited on these underlying pebbles and boulders. I am, however, by no means sure that this explanation is the correct one. The most remarkable, however, of the deposits at this horizon, are the strata of calcareous and other alkaline matters that are found in the upper portion of these silicious beds. The amount of alkaline matter ranges from ten to ninety per cent and the beds vary in thickness from a few inches to fifteen feet. Between Nebraska City and Brownville, along the Missouri bluffs, are some fine exposures of these alkaline beds, though they are more mingled with sand and gravel than farther west. The calcareous concretions found here are, however, exceedingly abundant and beautiful. Samples are common which measure from one to five inches in diameter. Inside they are sometimes partially hollow, and portions of the mass being separated and loose, they rattle, on being shaken after drying. In Saline County there is a thin, almost pure snow white layer of this calcareous matter. Further west, in Webster, Fillmore, Hamilton, York and some other counties north, as well as south of the Platte, this alkaline material occurs at this horizon at various localities. It differs greatly in thickness and extent of beds, and in the proportions of the alkalies present and silicious materials with which it is combined. It has sometimes been used for mortar and plastering, and from the people has received the name of natural mortar. It does not, however, avail for outside work, as the rain softens and gradually removes it. Not unfrequently layers of this alkaline matter are separated by layers of sand, and even higher up in the series, where it occurs in the Loess, as it sometimes does, it is separated into thin strata by the same materials. The following section, taken about five miles northwest from Fairmount, illustrates the mode of its occurrence:

1.	Black soil	4 feet.
2.	Loess	17 "
3.	Calcareous and other alkaline earths	1 "
4.	Loess	2 "
5.	Calcareous and other alkaline earths	7 "
6.	Brownish calcareous sand, exposed	3 "

The following analysis of these alkaline deposits show how they vary in character. Both specimens were obtained from Fillmore County:

	NO. 1.	NO. 2.
Insoluble (silicious) matter	21 00	55.11
Alumina	1.17	.79
Peroxide of iron	1.80	1.21
Lime carbonate	33.14	19.70
Lime phosphate, undetermined		
Magnesia carbonate, "	11.33	7.13
Potassa, "		
Soda, "		
Organic matter, "		
Moisture	3.80	4.01

These two specimens indicate the presence of a large quantity of magnesia and lime. Along the Missouri the alkaline concretions at this horizon are largely composed, in places, of magnesia. They are white in color and vary in size from a pea to from one to three inches in diameter. It is probable that a portion of the calcareous materials that are present in these deposits came from the chalk rocks of the Niobrara Group that still exists in northeast Nebraska and Dakota Territory. I have sometimes found in the Drift, and also mingled with other alkaline deposits, small chalk rock. At one place below Plattsmouth one of these chips of chalk contained a fish scale characteristic of the Niobrara Group. Among the eroded calcareous materials that were carried down into this lake the chalk rocks must have constituted a large portion. Evidently the waters became supersaturated with alkaline matter either by excessive activity of the eroding agents—ice and torrents—or, which is more probable, by partial dessication of the lake. We have an exemplification of this kind of agency in the present and past history of the lakes in the Utah basin. The analysis of its waters give a remarkably small per cent of carbonate of lime. And yet the rivers bring a large amount of it annually into the lake. King, however, has shown in the 40th parallel survey that lime in the form of tufa or thinolite has been precipitated in immense quantities during some portions of its history. When the waters of Salt Lake, (Lake Bonneville formerly, King), receded below the line of outflow, but were kept at a high level for long periods of time, great beds of tufa were deposited, especially along the shore, and to some extent towards its interior. Lake Lahontan (west of Lake Bonneville) is still a more remarkable instance where

calcareous tufas were produced. In reference to this, King remarks: "The occurrence of such a tremendous formation of alkaline carbonates, necessitates a very long period, during which the surface of Lake Lahontan was some distance below its level of outlet. To account for the existing presence of the weak solutions of the residual lakes, it is necessary, after the formation of gay-lussite and its pseudomorphism into thinolite, to suppose a flood-period during which the lake had free drainage over its outlet, and which continued long enough, practically, to wash out the saline contents of the great lake." Now in a way somewhat similar, it is possible that in immediately pre-Loess times, the great Quaternary lake of Nebraska and western Iowa, may have become so reduced in volume by climatic change as to lose more by evaporation than by overflow, and then through the interaction of other chemical agents, precipitated its alkalies to the bottom. That some such agency was here at work for a long time, is evident from the extent and great thickness of these alkaline deposits. When finally this condition of things was drawing to a close, the finer silicious deposits commenced to form, which shaded into the Loess or next deposit above. As already observed, these transition beds can be seen in the Republican Valley, and with still greater distinctness in some of the small canyons in the region of the Loups, where often it is impossible to tell with exactness where the Loess or next deposit above begins.

Resume of Geological History between the Glacial and Loess Periods.—We have seen that the retreating ice sheet of the Glacial Period left in its path huge beds of blue clay and other Drift materials, which in their upper portions were modified by water agency. The land was flooded, and over the great lake or interior sea thus formed icebergs floated and dropped their loads of sand, gravel and boulders on the bottoms, and where they were stranded left this debris in enormous heaps. This period of depression and floods was followed by one of slow elevation, when the waters were drained off and a new forest bed was formed to the shores of the retreating lakes, or to the foot of the glacier mass. As the period of glaciation was a time of great relative humidity, this must also have been the character of the climate all through the flood and Old Forest Bed period. The ice sheet again advanced and destroyed these magnificent forests before it. Newberry, who first directed attention to this Old Forest Bed, found no evidences

of this period of glaciation in Ohio. Here, however, it is clear. It has also been observed in northeastern Iowa by W. J. McGee.* I attribute the absence of this Forest Bed in many sections of Nebraska to the second advance of the ice sheet in these regions. It probably failed to advance so far south in Ohio and other sections of the Mississippi Valley. When this ice sheet commenced its retreat, another period of depression came on, when the land was again flooded, and a lake of fresh water again occupied the plains.

This body of water for ages abutted against the ice sheet on the north, from which it received icebergs that floated over its waters. In these waters the materials left by the retreating glaciers were remodified in their upper portion, and new matter was brought down by torrents and icebergs. When the ice sheet retreated from the shores of this lake or interior sea, finer sediment began to be laid down. Fine sand took the place of gravels and boulders, and as the waters contracted in volume the calcareous matter held in suspension began to be precipitated. There is no evidence that the lake was entirely dessicated previous to the beginning of the Loess period. It was only reduced to smaller dimensions. When at last central and eastern Iowa became dry land, and the ice sheet had retreated to the upper Missouri and the Yellowstone, the Loess materials began to be laid down on the floor of the old lake bed. So important, however, are these Loess materials in historic and economic geology that they will be discussed in a separate chapter.

*See American Journal of Science and Arts, Vol. 15, page 339.

CHAPTER VIII.

THE QUATERNARY AGE, AND SUPERFICIAL DEPOSITS, CONTINUED. LOESS PERIOD.

Name.—Extent.—Thickness.—Homogeneous Character.—Chemical Character.—Analyses.—Drainage.—Physical Character. — Example.—Cause of these Peculiarities of the Loess.—Fruit on the Loess deposits.—Scenery produced by the Loess.—Origin of the Loess.—Richthofen's Theory.—Recent Advocates of this Theory.—Facts bearing out this Theory in the Nebraska Loess.—Objections to this Theory.—Root Marks and their depth in the Nebraska Loess.—How Explained on the Subaqueous Theory.—Facts learned from Sections in the Republican Valley and South of Plum Creek.—Changes of Level Proved, by Fossil Soils in the Loess.—Differences in the Present Level of Loess Districts, and its Causes.—Land and Fresh Water Shells in the Loess, and How Explained.—Stratification of Loess, and its Lessons.—True Origin of the Loess.—Resume of its History.—Missouri Mud, its Analysis and Identity with the Loess.—Length of the Loess Period.—Remains of Man.—Climate.—List of Shells in the Loess.

The Loess Deposits.

The Loess deposits first received the name from Lyell, who observed it closely along the Mississippi in various places. Hayden frequently calls it the bluff formation, because of the peculiar configuration that it gives to the uplands which border the flood plains of the rivers. He also frequently calls them marl-beds. This deposit, although not particularly rich in organic remains, is in some respects one of the most remarkable in the world. Its value for agricultural purposes is not exceeded anywhere. It prevails over at least three-fourths of the surface of Nebraska. It ranges in thickness from five to one hundred and fifty feet. Some sections of it in Dakota County measure over two hundred feet. At North Platte, 300 miles west of Omaha, and on the south side of the river, some of the sections that I measured ranged in thickness from one hundred and twenty-five to one hundred and fifty feet. From Crete, on the Burlington & Missouri River Railroad, west to Kearney, on the Union Pacific Railroad, its thickness for ninety

miles ranges from forty to ninety feet. South of Kearney, and for a great distance west, along the Union Pacific Railroad as far as to the Republican, there is a great expanse of territory covered by a great thickness of this deposit. I measured many sections in wells over this region, and seldom found it less than forty, and often more than sixty feet in thickness. Along the Republican I traced the formation almost to the western line of the State, its thickness ranging from thirty to seventy feet. One section north of Kearney, on Wood River, showed a thickness of fifty feet. The same variation in thickness is found along the counties bordering on the Missouri. One peculiarity of this deposit is that it is generally almost perfectly homogeneous throughout, and of almost uniform color, however thick the deposit, or far apart the speeimens have been taken. I have compared many specimens taken 300 miles apart, and from the top and bottom of the deposits, and no difference could be detected by the eye or by chemical analysis.

Over 80 per cent of this deposit is very finely comminuted silica. When washed in water, left standing, and the water poured off, and the coarser materials have settled, the residuum, after evaporation to dryness, is almost entirely composed of fine silicious powder. So fine, indeed, are the particles of silica, that its true character can alone be detected by analysis or under a microscope. About ten per cent is composed of the carbonates and phosphates of lime. These materials are so abundant in these deposits, that they spontaneously crystalize, or form concretions, from the size of a shot to that of a walnut; and these are often hollow or contain some organic matter, or a fossil, around which the crystallization took place. Almost anywhere, when the soil is turned over by the plow or in excavations, these concretions may be found. Often, after a rain has washed newly-thrown-up soil, the ground seems to be literally covered with them. Old gopher hills and weather beaten hill-sides furnish these concretions in unlimited quantities for the geologist and the curiosity hunter. When first exposed, most of these concretions are soft enough to be rubbed fine between the fingers, but they gradually harden by exposure to the atmosphere. This deposit also contains small amounts of alkaline matter, iron, and alumina. For the purpose of showing the homogeneous character and the chemical properties of the Loess deposits, I have made five new analyses of this soil. No. 1 is from Douglas County, near Omaha; No. 2 from the bluffs near Kearney; No. 3 from the

Lower Loup; No. 4 from Sutton, and No. 5 from the Republican Valley, near Orleans, in Harlan County:

	NO. 1.	NO. 2.	NO. 3.	NO. 4.	NO. 5.
Insoluble (silicious) matter	81.28	81.32	81.35	81.30	81.32
Ferric oxide	3.86	3.87	3.83	3.85	3.86
Alumina	.75	.75	.74	.73	.74
Lime carbonate	6 06	6.06	6.03	6.05	6.09
Lime, phosphate	3.59	3 59	3.58	3.57	3.59
Magnesia, carbonate	1.28	1.28	1.31	1.31	1.29
Potassa	.27	.29	.35	.34	.33
Soda	.15	.16	.14	.16	.16
Organic matter	1.07	1.06	1.05	1.06	1.06
Moisture	1.09	1.08	1.09	1.08	1.09
Loss in analysis	.59	.54	.53	.55	.47
	100.00	100 00	100.00	100.00	100.00

After making the above analyses I received from Dr. Hayden his Final Report on the Geology of Nebraska. This report, on page 12, contains two analyses of the Loess deposit from Hannibal, Mo., made by Dr. Litton. According to these analyses, from one hundred parts there were—

	No. 1.	No. 2.
Silica	76.98	77.02
Alumina and peroxide of iron	11.54	12.10
Lime	3.87	3.25
Magnesia	1.68	1.63
Carbonic acid	Not determined	2.83
Water	2.01	2.43
	96.17	99.26

According to these analyses the Loess contains more clay in Missouri than it does in Nebraska. The analyses that I made of two specimens of Loess from Richardson County also contained slightly more alumina than the above.

For the purpose of comparison, I here reproduce, from Hayden's report, Bischoff's analyses of the Lacustrine or Loess of the Rhine:

	NO. OF ANALYSIS.				
	1.	2.	3.	4.	5.
Silicic acid	58.97	79.53	78.61	62.43	81.04
Alumina	9.97	13 45	15.26	7.51	9.75
Peroxide of iron	4.25	4 81		5.14	6.67
Lime	0 02	0 02	.....	......	..
Magnesia	0.04	0 06	0.09	0.21	0.27
Potash	0.11	1.05	3.31	1.75	2.27
Soda	0.84	1.14			
Carbonate of lime	20.16	......	......	11.63	......
Carbonate of magnesia	4.21	......	......	3.02	......
Loss by ignition	1.37	.. ...	1.89	2.31	......

It will be seen from the above analyses of Bischoff that Nos. 3 and 5, in the quantity of silica and other elements that are present, come very near the Loess of Nebraska. The principal difference is the larger quantity of alumina present in the samples analyzed by Bischoff. Chemically the deposits of the Rhine Valley, as Hayden remarks, are not essentially different from those of the Loess soils along the Missouri.

As would be expected, from the elements which chemical analysis shows to be present in these deposits, it forms one of the best soils in the world. In fact, it can never be exhausted until every hill and valley of which it is composed is entirely worn away. Its drainage, which is the best possible, is owing to the remarkably finely comminuted silica of which the bulk of the deposit consists. Where the ground is cultivated the most copious rains percolate through the soil, which, in its lowest depths, retains it like a huge sponge. Even the unbroken prairie absorbs much of the heavy rains that fall. When droughts come the moisture comes up from below by capillary attraction. And when it is considered that the depth to the solid rock ranges generally from five to two hundred feet, it is seen how readily the needs of vegetation are supplied in the driest seasons. This is the main reason why over all the region where these deposits prevail the natural vegetation and the well-cultivated crops are rarely dried out or drowned out. I have frequently observed a few showers to fall in April, and then little more rain until June, when, as will be considered farther on, there is generally a rainy season of from three to eight weeks' continuance. After these June rains little more would fall till autumn; and yet, if there was a deep and thorough cultivation, the crops of corn, cereals and grass would be most abundant. This condition represents the dry seasons. On the other hand, the extremely wet seasons only damage the crops over the low bottoms, subject to overflow. Owing to the silicious nature of the soils they never bake when plowed in a wet condition, and a day after heavy rains the plow can again be successfully and safely used.

The physical properties of the Loess deposits are also remarkable. In the interior, away from the Missouri, hundreds of miles of these Loess deposits are almost level or gently rolling. Not unfrequently a region will be reached where, for a few miles, the country is bluffy or hilly, and then as much almost entirely level, with intermediate forms. The bluffs that border the flood-plains of

the Missouri, the Lower Platte, and some other streams, are sometimes exceedingly precipitous, and sometimes gently rounded off. They often assume fantastic forms, as if carved by some curious generations of the past. But now they retain their forms so unchanged from year to year, affected by neither rain nor frost, that they must have been molded into their present outlines under circumstances of climate and level very different from that which now prevails.

For all purposes of architecture this soil, even for the most massive structures, is perfectly secure. I have never known a foundation of a large brick or stone building, if commenced below the winter frost line, to give way. Even when the first layers of brick and stone are laid on top of the ground there is seldom such unevenness of settling as to produce fractures in the walls. On no other deposits, except the solid rock, are there such excellent roads. From twelve to twenty-four hours after the heaviest rains the roads are perfectly dry, and often appear, after being traveled a few days, like a vast floor formed from cement, and by the highest art of man. The drawback to this picture is that sometimes during a drought the air along the highways on windy days is filled with dust. And yet the soil is very easily worked, yielding readily to the spade or plow. Excavation is remarkably easy, and no pick or mattock is thought of for such purposes. It might be expected that such a soil readily yielded to atmospheric influences, but such is not the case. Wells in this deposit are frequently walled up only to a point above the water line; and on the remainder the spade-marks will be visible for years. Indeed, the traveler over Nebraska will often be surprised to see spade-marks and carved-out names and dates years after they were first made, where ordinary soils would soon have fallen away into a gentle slope. This peculiarity of the soil has often been a God-send to poor emigrants. Such often cut out of the hillsides a shelter for themselves and their stock. Many a time when caught out on the roads in a storm, far away from the towns, have I found shelter in a "dug-out" with an emigrant's family, where, cozy and warm, there was perfect comfort, with little expenditure of fuel on the coldest days.

In summer such shelters are much cooler than frame or brick houses. I shall never forget one occasion in 1866 when, bewildered by a blinding snow-storm, I came to a "dug-out," and although all

the chambers were carved out of the soil (Loess), they were perfectly dry. The walls were hidden and ornamented with *Harpers' Weekly*, with the emanations of Nast's genius made to occupy the conspicuous corners. My hostess, whose cultivated intellect and kindly nature made even this abode a charming resort, was a graduate of an eastern seminary. Her husband, after a failure in business in New York, came here to commence life anew on a homestead, by stock raising. To get a start with young stock no money could be spared for a house. Eight years afterward I found the same family financially independent, and living in a beautiful brick mansion, but I doubt whether they had any more substantial happiness than when they were looking for better days in the old temporary "dug-out." Thousands who are still coming into this land of promise are still doing the same thing. So firmly does the material of this deposit stand, that after excavations are made in it, underground passages without number could be constructed without meeting any obstacles, and without requiring any protection from walls and timber.

Cause of these Peculiarities.

These peculiarities of the Loess deposits are chiefly owing to the fact that the carbonate of lime has entered into slight chemical combination with the finely comminuted silica. There is always more or less carbonic acid in the atmosphere which is brought down by the rains, and this dissolves the carbonate of lime, which then readily unites with silica, but only to a slight extent, and not enough to destroy its porosity. Though much of the silica is microscopically minute, and is water-worn or rounded, it still enters into this slight union with the carbonate of lime. Had there been more lime and iron in this deposit, and had it been subjected to a greater and longer pressure from superincumbent waters, instead of a slightly chemically compacted soil, it would have resulted in a sandstone formation, incapable of cultivation. There is not enough of clayey matter present to prevent the water from percolating through it as perfectly as through sand, though a great deal more slowly. This same peculiarity causes ponds and stagnant water to be rare within the limits of this deposit. Where they do exist in slight depressions on the level plain, it is found that an exceptionally large quantity of clayey matter has been accumulated in the soil on the bottom. In Clay, Fillmore, York, and a few other counties, there

are considerable numbers of ponds, covering from a few acres to half a section of land, grown up around the border with reeds and coarse grasses and sedges, and where the water is deeper, with arrow-leaves, pond-lillies, and other water-plants. In every instance where I had opportunity to examine them, there was a thin bed of clayey matter mixed with organic materials, from a few inches to a foot or more in thickness, lying on the bottom, and on top of the Loess deposit. This clayey matter was probably deposited there before the waters finally retired from the old lake-bed in which this soil originated. In the stiller portions of the lake, or in eddies, about the time it commenced to be dry land, when portions were already cut off from the main lake except in flood-time, in these isolated pools all the clay in solution would be precipitated to the bottom, before the next annual rise of the waters. This I propose as a provisional explanation of this phenomenon.

Fruit on the Loess Deposits.

In these Loess deposits are found the explanation of the ease with which nature produces the wild fruits in Nebraska. So dense are the thickets of wild grapes and plums along some of the bottoms and bluffs of the larger streams that it is difficult to penetrate them. Over twenty varieties of wild plums have been observed, all of them having originated either from *Prunus Americana*, *P. chickasa*, or *P. pumillo*. Only two species of grapes are clearly outlined, namely, *Vitis œstivalis* and *V. cardifolia*, but these have such interminable variations that the botanist becomes discouraged in attempting to draw the lines between them, and to define the range and limit of the varieties. The same remark could be made of the strawberries. Raspberries and blackberries abound in many parts of the State. The buffalo-berry (*Shepherdia Canadensis*) is common on many of the Missouri and Republican River bottoms. Many other wild fruits abound, and grow with wonderful luxuriance wherever timber protects them and prairie fires are repressed. As would be expected, these deposits are also a paradise for the cultivated fruits of the temperate zones. They luxuriate in a soil like this, which has perfect natural drainage, and is composed of such materials. No other region, except the valleys of the Nile and of the Rhine, can, in these respects, compare with the Loess deposits of Nebraska. The Loess of the Rhine supplies Europe with some of its finest wines and grapes. The success that has al-

ready attended the cultivation of the grape in southeastern Nebraska, at least, demonstrates that the State may likewise become remarkable in this respect. For the cultivation of the apple, its superiority is demonstrated. Nebraska, although so young in years, has taken the premium over all the other States in the pomological fairs at Richmond and Boston. Of course there are obstacles here in the way of the pomologist as well as in other favored regions. But what is claimed is, that the soil, as analysis and experience prove, is eminently adapted to grape, and especially to apple tree culture. The chief obstacle is particularly met with in the interior of the State, and results from the climate. In midsummer occasional hot, dry winds blow from the southwest. These winds, where the trunks of apple trees are exposed, blister and scald the bark on the south side, and frequently kill the trees. It is found, however, that when young trees are caused to throw out limbs near to the ground, they are completely protected, or if that has not been done, a shingle tacked on that side of the tree prevents all damage from that source. Many fruit-growers also claim that cottonwood and box-elder groves on the south side of orchards is all that is necessary to protect them from these storms. I mention this here to put any new settler, who may read this and who has not learned the experience of fruit-growers in this State, on his guard.

Scenery of the Loess Deposits.

It has been remarked that "no sharp lines of demarcation separate the kinds of scenery that produce the emotions of the grand and the beautiful." This is eminently true of some of the scenery produced by the Loess formations. Occasionally an elevation is encountered from whose summit there are such magnificent views of river, bottom, forest, and winding bluffs as to produce all the emotions of the sublime. One such elevation is Pilgrim Hill, in Dakota County, on the farm of Hon. J. Warner. From this hill the Missouri bottom, with its marvelous, weird-like river, can be seen for twenty miles. Dakota City and Sioux City, the latter distant sixteen miles, are plainly visible. If it happens to be Indian summer, the tints of the woods vie with the hazy splendor of the sky to give to the far outstretched landscape more than an oriental splendor. I have looked with amazement at some of the wonderful canyons of the Rocky Mountains, but nothing there more completely filled me and satisfied the craving for the grand in nature

than did this view from Pilgrim Hill. Another view, equally majestic is on the Missouri, back of Iona, in Dixon County. My attention was directed to it by John Hill, Esq., who took me to a high point for observing the river, which can here be seen for a great distance. The alternations of lofty bluff and bottom, woodland and prairie, give a picture worthy the pencil of the most gifted artist, and of all who love the grand and picturesque in nature. It is true that such scenes are rare, but then there are many landscapes which, if not grand, are still of wonderful beauty. This is the case along most of the bluffs of the principal rivers. In Northern Nebraska these bluffs often reach two hundred or more feet in height, and this perhaps gives this portion of the State the most varied scenery. At some points these bluffs are rounded off and melt beyond into a gently-rolling plain. But they constantly vary, and following them you come now into a beautiful cove, now to a curious headland, then to terraces, and, however far you travel, you in vain look for a picture like the one just passed. Numerous rounded tips, with strangely precipitous sides, are seen in every hour's travel, and these, as they form bold curves, rampart like, stretch away into the distance and form images of the most impressive beauty. Indeed, the bluffs of the Loess deposits are unique, and Ruskin cannot exhaust the subject of the beautiful until he sees and studies the hills of Nebraska.

Origin of the Loess Deposits.—Richthofen's Theory.—In a paper on "The Superficial Deposits of Nebraska," which was published in the Hayden Reports for 1874, I attributed the formation of the Loess deposits to subaqueous agency. Since then renewed attention has been given to the Loess, which has been stimulated by Baron Von Richthofen's great work on the Loess of northeastern China. He took the ground, as a few American geologists had previously suggested, that the Loess was a subaerial formation. So cogent is his reasoning that some American geologists, who I am satisfied had never thoroughly studied the American Loess in place, have been converted to his views. An examination, therefore, of this reference here, is not out of place, especially as this theory, if true, would have the most important application to the climatology of the plains.

Richthofen's theory is that the Loess of China, and the Loess everywhere, was formed on dessicated regions covered by scanty grasses, by the action through countless centuries of strong winds.

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The exigencies of his theory require that mountain chains should cut off the moisture from a contiguous, elevated, undrained region. The dessication of such a region exposed to dry, cold winds furnished the dust-like materials that filled up lower lands and became the Loess of this period. Prof. Pumpelly, contrary to his former views, now advocates this theory.* Clarence King now also lends to this theory a qualified assent. These eminent men would account for the Loess of Nebraska in the same way.

I admit that some facts concerning the Loess of Nebraska could be explained by this theory. One of these is the wind structure of some of the Loess hills on the Logan, Elkhorn, Loup and Republican rivers. This structure is often found there as distinct as among the shifting sands of our sea coast. In every case, however, where I examined this structure in the Loess I found it to be superficial. Out of nineteen such hills none of them possessed this structure over ten feet deep, and few of them over five feet, and many of them only from two to three feet deep. In the deep canyons where the Loess is exposed vertically from fifteen to one hundred feet I have never found this wind structure over ten feet deep. It occurs, therefore, only in the Loess that has been recently modified by the winds, and long after it was first deposited.

Another fact which the theory of a subærial origin would explain, is that the terraces in the valley of Oak Creek and Little Salt are formed of Loess, but the high plateau or divides between these streams are Drift. There are other similar cases in the State, where the Loess is comparatively thin. It is natural to suppose that if the Loess had been a subaqueous deposit, it would have been laid down on the uplands as well as in the valleys—if formed subærially, the valleys would have been filled up first. In other sections, however, the Loess covers with equal thickness uplands and the flanks of the valleys. West of Crete, as far as the Loess extends, it was probably laid down alike on hills and valleys, with only a few unimportant exceptions. In Dakota and Dixon counties, in southern Cedar, and many counties west of these, the Loess frequently is as thick on the high hills as in the terraced valleys. The isolated uplands now devoid of Loess, on the theory of its subaqueous origin, must have been islands in this old Nebraska lake, or else it has been removed by erosion. There are some facts that point to the former theory—the island origin of these spots de-

*See American Journal of Science and Arts for January, 1879.

void of Loess—as the correct explanation. One of these is that in such sections the Loess that borders on to an exposed Drift region is exceptionally full of the remains of elephants and mastodons. As if these animals had come down to the water to drink and to wallow, and had become mired and perished. This is proposed, however, as only a provisional explanation.

Another observation depended on by Richthofen to substantiate his theory is the depth at which root holes are found in the Loess. He supposes these to occur at such a depth that the grasses that occur at the surface could not possibly have penetrated the Loess to such a depth, and that therefore they must have flourished when this deposit was thinner than at present. Subærial filling up would account for their presence, as they would be growing during the whole period of the accumulation of the Loess. To this it may be replied that roots descend from the surface through the Loess to an enormous depth. In 1868 I measured the depth of a root of the Buffalo berry (*Shepherdia argophylla*), at the edge of the St. John's timber, in Dakota County, and found it to extend fifty-five feet below the surface in undisturbed Loess. Near the same point, I traced another root from near the bottom of the Loess in a slide for thirty-nine feet to a stock of grass (*Andropogon furcatus*). West of old Fort Calhoun the roots of the common blue-grass have penetrated the Loess to a depth of from five to fifteen feet. A sumach (*Rhus glabra*) near by was found to send down roots to a depth of fifteen feet. South of Plum Creek, in the Loess canyons, roots of the lead plant (*Amorpha canescens*), can be traced in the Loess for from ten to twenty feet. Prof. J. E. Todd has also observed in the Iowa Loess the roots of other grasses to descend to depths of from six to twenty-five feet.* Moreover, these root marks inosculate in every direction, and become fewer the deeper we descend, with some notable exceptions. There are horizons in the Republican Valley, far below the present surface, where the old root marks occur in exceptional numbers. As these fossil root marks are now more or less completely filled with either lime carbonate or oxides of iron, they are readily distinguished. To understand the probable reason for these phenomena, on the theory of the subaqueous origin of the Loess, the following sections are given. The first is taken from along the sides of a canyon leading into a tributary of the

*Proceedings of the American Association for the Advancement of Science, Vol. 27, St. Louis Meeting, August, 1878.

Republican, in Township 27 West, 1 and 2 North. It is exposed for many miles:

1.	Loess	4 feet.
2.	Black soil	2 "
3.	Loess extending down to upper terrace	4 "
4.	Black soil	1½"
5.	Loess	5 "
6.	Black soil	1½"
7.	Stratified loess	15 "

Another section, taken two miles above the Republican Forks in Dundy County, from the sides of a small tributary, showed the following characters:

1.	Black soil	1 foot.
2.	Loess	5 feet.
3.	Black soil	1 foot.
4.	Loess	15 feet.

The following section was taken near the Arickeree, about six miles east of the west line of the State. This section can be duplicated in any of the numerous small canyons in this region:

1.	Black soil	1½ feet.
2.	Loess	15 "
3.	Black soil	2 "
4.	Loess as far as exposed	15 "

Now, in all these sections the Loess next to the Black soils from below is specially full of root marks—the Loess at the bottom of the sections as well as at the top. This indicates that during the progress of the Loess period there were many changes of level, during some of which these regions became level surfaces, similar to the present, and covered with a rich black soil. These old land surfaces became covered with grasses, whose roots penetrated far into the underlying Loess. Changes of level, and lake conditions came on again, and deposited more Loess, and these changes, continuing through interminable centuries, have gone on till the present.

To show that the Republican region was not exceptionable in this respect, the following section is given, from the canyon region south of Plum Creek, on the road to Arrapahoe. It is near the divide between the Platte and Republican:

1.	Black soil	3 feet.
2.	Loess	40 "
3.	Black soil	2 "
4.	Loess	15 "
5.	Clay with calcareous concretions	4 "
6.	Reddish sandy deposit, with a few calcareous concretions, only two feet exposed	2 "

Here, as in the Republican Valley, the Loess at the bottom of the section (No. 4) has a great many more root marks than the lower part of the Loess above (or No. 2). The same explanation is applicable here as in the former case, namely, that these fossil black soils represent conditions of land surface like the present, when the vegetation of the time penetrated from them into the underlying Loess. Now it is probable that these black soils may have been removed in some districts by erosion at the beginning of the renewed lake conditions, and left no sign of their former presence, except the fossil root marks below. However abundant, therefore, at some horizons these root marks may be in the Loess of this country or Asia, its origin can easily be explained on the theory of its sub iqueous origin. Again, it is questionable whether these black soils filled with organic matter are ever formed except in the presence of water. The most probable explanation is that the black soils on top of the Loess have been formed when this lake gradually approached dessication or a drained condition. When it approximated the condition of a peat bog the organic matter was retained (as a large portion is always retained when it decays under water), and mingling with the Loess bottom became a black soil when the drainage was completed. This semi-boggy condition endured for ages—long enough at least to form a black soil from three inches to ten feet thick. In accordance with this view the highest knolls where the land is rolling have in general the thinnest covering of black soil. This process is still going on in the bogs of the Missouri and many of its tributaries in the Loess region. If the Loess was formed, as I maintain, by subaqueous agency, then it is apparent that this old lake became dry land gradually. It surrendered its bottom little by little, until modern conditions prevailed.

Another fact depended on by Richthofen to substantiate his theory, is the difference in level between various points of connected Loess regions. This objection is based on the assumption that the Loess districts lie at the same level now as during the deposition of this peculiar sediment. No geologist, however, doubts that during Glacial times the continent towards the north laid relatively far above its present level. It is also conceded that during the Champlain Epoch the level of a large part of North America was below what it is now. It is admitted that, partly owing to this depression, and partly to melting ice sheets, temperate latitudes were flooded. The re-elevation of the land drained it.

Probably the huge terminal morraines helped to confine the water and produce the great lakes of the time. Now it can easily be seen that a certain stage would be reached in the re-elevation of the land when the surface conditions would be precisely such as is claimed for the great lakes of the Loess period. Confirmatory of this induction is the fact that the Loess valleys running proximately east and west through Nebraska have almost universally long gentle slopes on the north side and steeper bluffs on the south. As the continent rose towards the north slowly and gently, the streams retired gradually towards the south side of the valleys and produced this peculiar configuration. It is true that here the Loess in southeast Nebraska is over 3,000 feet below the highest point on the west line of the State. At other points the difference of level in the Loess of Nebraska is over 3,500 feet. But this is more than paralleled by the remnants of the old Pliocene lake of the plains, where the present difference of level between its eastern and western shore is over 7,000 feet. No geologist, however, doubts that in Pliocene times it occupied about the same plane. The change in level, therefore, on the theory that the Loess was formed in a lake, since the close of that period, is only about half as great as that which occurred since the close of Pliocene times.

The assumed fact that fresh water shells are absent and land shells abundant in the Loess, is also depended on by Richthofen to prove his theory. However it may be in China, here fresh water shells are quite abundant at some horizons. The species of land and fresh water shells that I have thus far identified from the Loess of Nebraska are appended to the end of this chapter. It will be seen that large numbers of them are fresh water shells. They are not found merely near existing fresh water streams, as has been suggested—they are equally abundant on the divides wherever there are well shafts to bring them to light. It is an interesting analogous fact that in the eddies and in the sand bars and silted up hollows of the Missouri, at the present time, about the same relative proportion of land and fresh water shells are found as in the Loess. For example, four miles below Dakota City, on a sand bar, I have on several occasions examined the exposed silt after flood time for shells. In 1871 I here obtained of existing kinds brought down by the river, thirty-five species of land and twenty of fresh water shells. Three years afterwards, at the same point, I obtained five less of the former and six of the latter. The Mis-

souri, in its upper portion at least, is not rich in fresh water shells, neither its bottoms nor waters being highly adapted to them. This evidently also was the case with the Loess lake of this region, which was fed, as we shall presently see, by the Missouri and the Platte. I do not adopt the views suggested by Hilgard that the waters of this lake, probably from its alkaline character and the constitution of the Loess itself, destroyed the more fragile shells.* As in the Missouri at the present time, there were comparatively few shells in this old lake. Even a large part of the fresh water shells now found in the Loess were probably carried into this lake from its smaller tributaries.

Richthofen also claims that the Loess exhibits no marks of stratification, and that therefore it could not have been formed by subaqueous agencies. In my earlier studies of the Loess it also appeared to me to be without stratification. Since my earlier published papers on this subject, I have found the most convincing evidence that the Loess, at least in some sections, is as distinctly stratified as the modified Drift beneath it. The following section is given from the new railroad cut at Plattsmouth, to show the horizon of stratification. The section is taken from the east end of the cut:

1. Black soil.. 2 feet.
2. Yellow Loess ....10 "
3. Typical Loess, finely laminated ....30 "
4. Reddish brown, impure Loess, mingled with silicious streaks....15 "
5. Small boulders, gravel and lime concretions. Small boulders, sometimes covered with lime. Some clay. Colors, various. Exposed.. 6 "

In this section No. 3 is clearly stratified. A similar laminated appearance is seen in some of the Loess at the west or Plattsmouth end of this cut. In the Republican Valley the lower sections of the Loess are now found to be distinctly laminated and occasionally stratified. Here the strata of Loess are sometimes separated by strata of sand, and even, sometimes, on the upper Republican, by layers of sand and gravel. Similar sections can be seen in some of the canyons through the Loess southwest of Plum Creek. At Plattsmouth, and on the Lower Loup, beds of light are often separated by beds of darker colored Loess. Along the bluffs of the Republican Valley this condition can be observed for many miles in a stretch. Conspicuous examples can be seen going west from

*American Journal of Science and Arts, for April, 1879.

Orleans. I find, also, that almost any section of our Loess, when saturated with moisture and then frozen and shaved smooth with a knife, will show fine lines of stratification when looked at through a large magnifying glass

A fact often overlooked is the transition character of some beds of sand, as they shade into the Loess. As beds of Loess and stratified sands at the bottom of Loess sections often alternate, and even sometimes with strata of clay, it is not easily conceivable how subaqueous agency should have formed the one and æolian agency the other.

The preceding discussion disposes of the most important objections to the theory of the subaqueous origin of the Loess. The theory of Richthofen is not tenable, in my judgment, for the Nebraska Loess. I have no doubt that future investigation will show it to be untenable for China. We are now ready to state connectedly the history of the origin of the Loess.

True Origin of the Loess Deposits.—Geological events have already been traced to the beginning of the Loess period. According to Newberry the whole of the Old Forest Bed area now less than 1,100 feet above the level of Lake Erie was flooded by the changes of level and thawing of retreating glaciers that followed its disappearance. In Nebraska during this time icebergs again floated over the waters. The farther retreat of the glaciers and the elevation of eastern Iowa reduced the area of this great lake. What had been a great interior sea of turbulent waters had now become a system of placid lakes that extended from Nebraska and western Iowa at intervals to the Gulf. The Missouri drained through them all along its length. The Missouri, and sometimes the Platte, have been amongst the muddiest streams in the world. If we go up the Missouri to its source, and carefully examine the character of the deposits through which it passes, we cannot be surprised at its character. These deposits being of Tertiary and Cretaceous ages, are exceedingly friable and easy of disintegration. The Tertiary, and especially the Pliocene Tertiary, is largely silicious, and the Cretaceous is both silicious and calcareous. In fact, in many places the Missouri and its tributaries flow directly over and through the chalk-beds of the Cretaceous deposits. From these beds the Loess deposits no doubt received their per cent of the phosphates and carbonates of lime. Flowing through such deposits for more than a thousand miles, the Missouri and its tribu-

taries have been gathering for vast ages that peculiar mud which filled up their ancient lakes, and which distinguishes them even yet from most other streams. Being anciently, as now, very rapid streams, as soon as they emptied themselves into these great lakes, and their waters became quiet, the sediment held suspended was dropped to the bottom. While this process was going on in the earlier portion of this age, the last of the glaciers had probably not retreated farther than first a little beyond the boundary of the Loess lake, and then gradually to the headwaters of the Platte, the Missouri and the Yellowstone. The tremendous force of these mighty rivers was, for a while at least, aided by the erosive action of ice, and therefore must have been vastly more rapid at times than anything of the kind with which we are now acquainted. The following analysis of Missouri River sediment taken at high stage will show, by comparison with the analyses of the Loess deposits, what a remarkable resemblance there is even yet between the two substances.

In one hundred parts of Missouri River sediment, there are of—

Insoluble (silicious) matter	82.01
Ferric oxide	3.10
Alumina	1.70
Lime, carbonate	6.50
Lime, phosphate	3.00
Magnesia, carbonate	1.10
Potassa	.50
Soda	.22
Organic matter	1.20
Loss in analysis	.67
	100.00

Two other analyses which I made, the one from sediment at high water and the other at low water, differ somewhat from this, but in essential particulars are the same. This identity of chemical combinations also points to the remarkable sameness of conditions that have existed for long periods in the Upper Missouri and Yellowstone regions.

After these great lakes were filled with sediment (Missouri mud), they existed for a longer or shorter time, as already remarked, as marshes or bogs. Isolated portions would first become dry land, and as soon as they appeared above the water they were no doubt, covered with vegetation, which, decaying from year to year, and uniting under water or at the water's edge with the deposits at the

bottom, formed that black soil so characteristic of Nebraska prairies. For it is well known that when vegetable matter decays in water or a wet situation its carbon is retained. In dry situations it passes into the atmosphere as carbonic-acid gas. After the first low islands appeared in this old lake, they gradually increased from year to year in size and numbers.

The ponds and sloughs, some of which could almost be called lakelets, still in existence, are probably the last remains of these great lakes. These ponds, where they do not dry up in midsummer, swarm with a few species of fresh water shells, especially of the *Limnæs*, *Physæs*, and *Pianorbi*, which to me is strong proof of this theory of their origin. The rising of the land continuing, the rivers began to cut new channels through the middle of the old lake beds. This drained the marshes and formed the bottom lands, as the river beds of that period covered the whole of the present flood-plains from bluff to bluff. It was then that the bluffs which now bound these flood-plains received those touches from the hand of nature that gave them their peculiar steep and rounded appearance. Newer and more plastic, because less compactly bound and cemented together, the rains and floods easily molded them into those peculiar outlines which they have since preserved.

The Missouri, during the closing centuries of the Loess age, must have been from five to thirty miles in breadth, forming a stream which for size and majesty rivaled the Amazon. The Platte, the Niobrara, and the Republican covered their respective flood-plains in the same way. In the smaller streams of the State, those that originated within or near the Loess deposits, such as the Elkhorn, Loup, Bow, Blue, and the Nemahas, we see the same general form of flood-plain as on the larger rivers, and no doubt their bottoms were also covered with water during this period. Hayden, in his first reports, has already expressed the same opinion as to the original size of these rivers. Only a few geologists will dissent from this view. The gradually melting glaciers, which had been accumulating for so many ages at the sources of these great rivers, the vast floods of water caused by the necessarily moist climate and heavy rains, the present forms and materials of the river bottoms, are some of the causes which, in my opinion, would operate to produce such vast volumes of water.

The changes of level were not all upward during this period. The terraces along the Missouri, Platte and Republican indicate

that there were long periods when this portion of the continent was stationary. Several times the movement was downward. Along the bluffs in the Republican Valley, at a depth varying from ten to thirty feet from the top, there is a line or streak of the Loess mingled with organic matter. It is, in fact, an old bed, where vegetation must have flourished for a long period. It can be traced from Orleans upward in places for seventy-five miles. It indicates that after this bed had, as dry land, sustained a growth of vegetation, an oscillation of level depressed it sufficiently to receive a great accumulation of Loess materials on top of it. Other oscillations of this character occurred previously to and subsequent to this main halt. These have already been discussed. I have also found traces of this movement in many other portions of the State.

Length of the Loess Age.

The bases for speculation concerning the length of the Loess age are of course uncertain, yet an approximate estimate may perhaps be made by comparison with the present deposits of the Missouri. The great lakes of the Loess age extended, with a few interruptions, almost to the Gulf, and some of them covered an area of at least 75,000 square miles. Now, were all the sediment which is at present brought down the Missouri spread over such a vast area, the thickness of the deposit would be less than one sixteenth of an inch. Probably the yearly accumulations of sediment during the Loess age amounted to that much, owing to the then greater volume of the Missouri and the aids to erosion from the greater prevalence of ice near its sources. In many places along the Missouri there are small lakes, formed from the old river-bed, where there has been a cut-off. Even where these little lakes receive the overflow of the river each year, it often requires at least a century to fill them up, even when aided by the sands which the winds waft into them. I have attempted to measure the sediment left by the river in these lakes, which are seldom half a mile in breadth, and it rarely amounted to half an inch in a season. The winds are a much more efficient agent for filling up small, narrow lakes, but in Loess times, where there were such immense bodies of fresh water, their effects could only have been appreciable along the sandy shore-lines. The highest bluffs represent the original level of the Loess deposits before the tremendous denuding agencies which removed so much of their materials had done their work.

Now, in places these sediments are even yet 200 or more feet in thickness, so that it would be safe to estimate the average thickness of the original deposits at 100 feet. A yearly increase of one-sixteenth of an inch in thickness, would at this rate have required 19,200 years to form these deposits. This I consider a low estimate for the length of the Loess age.

Life of the Loess Age.

At the close of this chapter will be found a list of the land and fresh-water shells that I have found and identified in the Loess deposits. It will be seen that the list of land shells is quite large. These, no doubt, were brought into this old lake during flood-time. I have occasionally found large numbers of these shells where drift-wood had evidently lodged and decayed. The fresh-water and land shells are mainly such as are still to be found in the same region, the exceptions being the prevalence of a large number of southern forms at one horizon of these deposits. As will be seen, the species belong to quite a large number of genera.

Occasionally I have found the teeth and a stray bone of fish, but have not been able to identify any species. The remains of rabbits, gophers, otters, beavers, squirrels, deer, elk, and buffalo are frequently found. Through the entire extent of these deposits are many remains of mastodons and elephants, whose last vigorous life, as Newberry remarks, expired in high northern latitudes. Lancaster County is specially rich in these proboscidian remains. They are frequently found in this deposit in digging wells. In Lincoln they have been found in at least twenty wells that have been dug in and around the city. This town is near what appears to have been the western shore-line of the Missouri lake of the period. Between it and the Blue River at Crete, there is a high divide covered by Drift materials. These huge animals no doubt often here came down to the shore to drink, and playing in the water became mired in the mud. One tusk found in a well on P street, east of Twelfth, must have been at least eleven feet long when entire. It was so far decayed that it fell to pieces on exposure.

For years I have been closely watching for human remains in the Loess deposits. Eight years ago, three miles east of Sioux City, Iowa, in a railroad cut I found a small arrow-head in these deposits. I was looking for mollusks, and was digging after them with a large knife when I struck something hard, and, laying it

bare, to my great surprise and joy found it to be an arrow-head. So far as I knew, this was the first mark that had yet been discovered of the presence of man during this age. From that time onward I have seized every opportunity of exploring these deposits for human remains. The same year I found some flint chips in the bluffs back of Jackson, in Dakota County, but it was not absolutely clear that these were of human origin. My next find was about two and a half miles southeast of Omaha, in a railroad cut, where I found a large coarse arrow or spear-head. This last was found in 1874. It was found twenty feet below the top of the Loess, and at least six inches from the edge of the cut, so that it could not have slid into that place. The first found was fifteen feet below the top of the deposit. It appears, then, that some old races lived around the shores of this old lake, and paddled their canoes over its waters, and accidentally dropped their arrows in its waters or let them fly at a passing water-fowl. It is possible also that these arrows came into this old lake by drift-wood. I once found an arrow sticking in a log that came down the Missouri, and if it had continued on to the Gulf it might have been unearthed in the far-off future, when that portion of the continent at the mouth of the Mississippi had become dry land. Thirteen inches above the point where the last named arrow was found, and within three inches of being on a line with it, in undisturbed Loess, there was a lumbar vertebra of an elephant (*Elephas Americanus*). Unfortunately this vertebra partially fell to pieces on exposure. It appears clear from this conjunction of a human relic and proboscidian remains that man here as well as in Europe was the cotemporary of the elephant in at least a portion of the Missouri Valley.

In 1876 and again in the spring of 1877 I found additional arrowheads in the Loess of the Republican Valley. One in a section described on a previous page east of the Republican Forks in Dundy County. It was in the Loess below the second bed of black soil, or fourteen feet below the surface. Here, then, primeval man existed anterior to two old land surfaces, between which and after the last, this region again became the bed of a Loess lake. Hon. R. W. Furnas also found a hatchet in the Loess, five feet below the surface, in Brownville, Nebraska.

The climate probably varied considerably during the progress of this age. What inclines me to that view is the fact that about the middle horizon an unusually large number of southern species of

mollusks are found. This indeed is not conclusive, as this region is at this time remarkable for the presence of southern forms of insects and fresh-water mollusks* Yet it appears to me that an unusual number of southern forms at this horizon of the Loess must indicate some modification of climate at that period. It may have been only on the eastern shore of this great lake, and caused by the even temperature which so large a body of fresh water produces on the side toward which the prevailing winds from the lake blow. We have such a phenomenon at the present day on the east shore of Lake Michigan. The Mississippi Valley is by its contour eminently favorable to the emigration northward of southern species.

These Loess deposits, which have done so much to enrich Nebraska, have received profound attention and study from some of the ablest geologists. But in many of the counties of the State they have not yet been investigated. Much to be discovered must yet remain in them. Though myself long engaged in their investigation, I rarely examine a new section in a well, ravine or railroad cut without finding something new.

Close of the Loess Period.—It was a continuation of the upward movement that had again begun during the second depression epoch of the Quaternary that brought the Loess period to a final close. As the land rose most towards the west and north, the area of this Loess lake was gradually lessened from these directions, and its remnants were last active on its southeastern border. This explains the fact already mentioned in other connections, that the long gentle slopes of the bluffs bordering the flood-plains running in an easterly and westerly direction are almost universally on the north side of the valleys. The closing of the Loess period first clearly outlined the present rivers of Nebraska, when they covered the whole of the bottoms, from bluff to bluff, and when the mud-flats of the former Loess lake themselves constituted the flood-plain. So far as known, no convulsive movements to a certainty accompanied the close of this period. Many movements of this kind occurred in the regions of the mountains during the Quaternary, but they have not yet been synchronised with geological events on the plains.

*Hayden's Report for 1870, page 467.

Mollusks in the Loess Deposits.

The following list of land and fresh-water shells comprises all that I have thus far identified, in whole or in part, from the Loess deposits. Nearly all are extremely fragile. The Hyalinas, Pupas, and some of the Helices long eluded my efforts at identifying them. I finally marked the localities where found, until the ground was frozen, when they were cut out with a knife. They were then identified by making thin sections with a sharp knife. Many of these mollusks, after being placed for a while in my cabinet, fell to pieces. For this reason I have no specimens to show of many species here given, and, therefore, only present this as a provisional list. Some well-preserved specimens appear to me to be new to science, but as I have not access to the descriptions of the new species discovered by Hayden, a bare list of which is given in Binney's and Bland's Land and Fresh Water Shells, I will not venture to describe them, as that has probably already been done. The counties are indicated where the specimens were obtained, or where they were the most abundant.

In addition to my own list of species, which were first published in the Hayden Reports for 1874, Prof. J. E. Todd has given eighteen from the Loess of Iowa. Prof. Swallow also reports fifty species from the Loess of Missouri, twenty of which are fresh-water shells:

Vitrina limpida, Gould, Lancaster and Dixon Counties.
Hyalina nitida? Mueller, Dixon County.
Hyalina arborea, Say, Douglas and Dakota Counties.
Hyalina viridula, Monke, all Eastern Nebraska.
Hyalina indentata, Say, Otoe and Douglas Counties
Hyalina limatula, Ward, Douglas County.
Hyalina minuscula, Binney, all Eastern Nebraska.
Hyalina binneyana? Morse, Dixon and Cedar Counties.
Hyalina ferrea? Morse, Dixon County.
Hyalina exigua, Stimpson, Dixon and Cedar Counties.
Hyalina intertexta? Binney, Douglas County.
Hyalina ligera, Say, Otoe and Nemaha Counties.
Hyalina demissa? Binney, Nemaha and Richardson Counties.
Hyalina fulva, Dreparnaud, Dixon and Cedar Counties.
Hyalina lasmodon, Phillips, Nemaha and Otoe Counties.
Hyalina interna, Say, Nemaha and Otoe Counties.

Hyalina significans, Bland, Nemaha and Otoe Counties.
Hyalina lineata? Say, Douglas and Otoe Counties.
Macrocyclis concava, Say, Douglas and Otoe Counties.
Helix solitaria, Say, Otoe and Burt Counties.
Helix strigosa, Gould, Otoe and Burt Counties.
Helix alternata, Say, all Eastern Nebraska.
Helix cumberlandiana, Lea, Middle Loess in Nemaha and Otoe Counties.
Helix cooperi, W. G. B., Douglas and Washington Counties.
Helix striatella, Anthony, Dixon and Dakota Counties.
Helix labyrinthica, Say, all Eastern Nebraska.
Helix hubbardi, Brown, Middle Loess in Nemaha County.
Helix auriformis, Bland, Middle Loess in Otoe County.
Helix tholus? G. G. Binney, Middle Loess in Douglas County.
Helix fastigans, L. W. Say, Middle Loess in Otoe County.
Helix jacksonii? Bland, Middle Loess in Otoe County.
Helix hazardi? Bland, Middle Loess in Douglas County.
Helix dorfeuilliana, Lea, Middle Loess in Cass County.
Helix pustula? Fer, Middle Loess of Cass County.
Helix spinosa, Lea, Middle Loess of Harlan County.
Helix edgariana? Lea, Middle Loess of Richardson County.
Helix stenotrema, Fer, Otoe and Cass Counties.
Helix hirsuta, Say, Dixon and Cass Counties.
Helix monodon, Rackett, all Eastern Nebraska.
Helix palliata, Say, all Eastern Nebraska.
Helix abstricta? Say, all Eastern Nebraska.
Helix appressa? Say, Otoe and Nemaha Counties.
Helix inflecta, Say, all Eastern Nebraska.
Helix tridentata? all Eastern Nebraska.
Helix fallax, Say, all Eastern Nebraska and Republican Valley.
Helix albolabris, Say, Eastern Nebraska and Republican Valley.
Helix multilineata, Say, all Eastern Nebraska.
Helix pennsylvanica, Green, Douglas County.
Helix elevata, Say, Eastern Nebraska and Republican Valley.
Helix exoleta, Binney, Eastern Nebraska and Republican Valley.
Helix roemeri, Pfeifer, Middle Loess of Richardson County.
Helix thyroides, Eastern Nebraska and Republican Valley.
Helix clausa, Say, Eastern Nebraska.
Helix jejuna? Say, Richardson County.
Helix profunda, Say, all Eastern Nebraska and Republican Valley.

Helix pulchella, Mull, all Eastern Nebraska and Republican Valley.

Helix ———, Republican Valley.

Helix ———, Otoe and Nemaha Counties.

Helix ———, Otoe and Nemaha Counties.

Helix ———, Otoe and Nemaha Counties.

Helix ———, Dakota and Dixon Counties.

Helix———, Dakota and Dixon Counties.

Bulimulus dealbatus, Say, Middle Loess of Nemaha County.

Cionella subcylindrica, Linn., Southeastern Nebraska.

Pupa muscorum? Linn., Cedar County.

Pupa blandi, Morse, Dixon, Dakota and Burt Counties.

Pupa fallax, Say, Dixon, Dakota and Burt Counties.

Pupa armifera, Say, all Eastern Nebraska.

Pupa corticaria, Say, all Eastern Nebraska.

Succinea haydeni? W. G B., Republican Valley.

Succinea mooresiana, Lea, Republican Valley.

Succinea avara, Lea, Republican Valley.

Succinea obliqua, Say, Dixon and Dakota Counties.

Succinea ———, Otoe and Nemaha Counties.

Zonites fuliginosa, Griff, Republican Valley.

Zonites lævigata? Pfeifer, Republican Valley.

Zonites inornata, Say, Cass and Otoe Counties.

Zonites, gularis, Say, Southeastern Nebraska.

Carychium? exiguum? Say, Nemaha County.

Limnœa stagnalis? Linn., Washington County.

Limnœa reflexa, Say, Dakota and Dixon Counties.

Limnœa palustris, Mull., along Missouri Bluffs.

Physa gyrina, Say, Dakota County.

Physa heterostropha, Say, Douglas County.

Physa ———, Douglas County.

Physa ———, Douglas County.

Psulinus ———, Otoe County.

Planorbis glabratus, Say, Otoe County.

Planorbis campanulatus, Say, Dakota County.

Planorbis corpulentus? Say, Dakota County.

Planorbis deflectus, Say, Nemaha County.

Planorbis albus? Mull., Dixon County.

Ancylus ———, Dakota, Harlan County.

Valvata tricarinata, Say, Dixon County.

Valvata ———, Say, Otoe and Burt Counties.
Vivipara intertexta? Say, Otoe County.
Vivapara subpurpurea? Say, Otoe and Nemaha Counties.
Vivapara contectoides, Binney, Nemaha County.
Melantho ponderosa, Say, Washington County.
Melantho decisa, Say, Burt County.
Amnicola perata? Say, Washington County.
Amnicola lemnosa? Say, Washington County.
Pomatiopsis lapidaria, Say, Dakota County.
Helicina orbiculata, Say, Nemaha County.
Angitrema armigera, Say, Nemaha County.
Lithasia, obovata, Say, Richardson County.
Pleurocera undulatum? Harlan County.
Pleurocera canaleculatum, Say, Nemaha County.
Pleurocera elevatum, Say, Otoe County.
Pleurocera labiatum? Lea, Richardson County.
Pleurocera simplex? Lea, Otoe County.
Goniobasis depygis, Say, Richardson and Otoe Counties.
Goniobasis livescens? Menke, Richardson County.
Goniobasis brevispira? Anthony, Otoe County.
Goniobasis, semicaranata, Say, Otoe County.
Anculosa costata, Anthony, Richardson County.
Anculosa praerosa, Say, Richardson County.
Anculosa? ———, Richardson County.
Unio ———, Cedar, Dakota, and Burt Counties.
Unio ———, Nemaha County.
Unio ———, Otoe and Cass Counties.
Anadonta ———, Washington County.
Anadonta ———, Republican Valley.

CHAPTER IX.

QUATERNARY AGE AND SUPERFICIAL DEPOSITS, CONTINUED.—TERRACE EPOCH.—ALLUVIUM.—SAND HILLS.—ALKALI LANDS.—TIMBER, AND CAUSE OF CHANGES OF CLIMATE.

Relationship of the Terrace Epoch to Subsequent Times.—Level of the Land.—Gradual Formation of Terraces.—Highest Elevation Reached, and its Effects in the West.—Section Showing Glacial Action.—Effect of Extreme Elevation on River Channels.—Varying Heights of Terraces.—Alluvium.—Its importance, and How Gradually Produced.—Character of the Bottom Lands, and their Great Extent.—Analysis of Alluvium.—Sand Hills, and their Extent and Geological Character.—Theories about their Origin.—Pliocene Origin of Many of Them.—Capabilities for Cultivation.—Alkali Lands.—Extent and Character.—Analysis of Alkali Soils.—How to Cultivate Them.—Hard-pan, or "Gumbo" Soils.—Their Character, Extent and Analysis.—Bad Lands.—Their Superficial Character and Appearance.—Organic Remains, and Agricultural Character.—Fuel from the Surface Deposits.—Peat.—Its Extent and Character.—Timber in Modern Geological Times.—Causes of Changes of Climate.

TERRACE EPOCH.

FROM the preceding, it is evident that the Terrace Epoch in Nebraska is closely connected with that order of events and with those changes that finally resulted in the present order of things. It commenced here after the close of the Loess period. When the rivers covered the whole of the existing bottoms, and had the old Loess lake bed for a flood-plain, the land still lay far below its present level, and was in the transition stage between the Loess and Terrace periods. When the elevation became a little greater, and the drainage better, and the volume of water less, it cut a new channel amid its old bed, which now constituted its flood-plain. This formed the first terrace, and fully inaugurated this epoch. Here the land and the river must have stood for ages. Again there was an upward movement, the drainage became still better, the volume of water lessened, and another channel formed, and the previous river bed changed to a flood-plain. Thus terrace

after terrace was formed, each representing a stage of quiet in the upward movement of the land. There are some indications that this upward movement continued until this section of the continent stood considerably above its present level. This is known to have been the case in Europe, where even local glaciers were formed at this time, which disappeared only when a movement in the opposite direction had once more brought the land to a lower level. The following section indicates some movement of this kind for extreme southwestern Nebraska. It was taken in a canyon leading into the Republican Valley, immediately west of the west line of the State in Colorado. I saw similar sections, however, on the Nebraska side of the State line:

1. Black soil	1	foot.
2. Drift	2	feet.
3. Alluvium	2	"
4. Black soil	.75	"
5. Alluvium	4	"
6. Loess	4	"
7. Alluvium	4	"
8. Black soil	1	foot.
9. Loess and Drift	4	feet.
10. Black soil	1.25	"

This section tells its own story—a history of frequent changes of level. After the last Loess was laid down, river alluvium was deposited, on top of which appeared a black soil, which was again flooded and covered with alluvium. On top of the last, Drift material, which most nearly resembles glacial Drift, was formed, which in turn gave way again to the present black soil of this region. It would not be surprising if further investigation should confirm the explanation suggested above—that the upward movement of the Terrace Epoch continued until a much higher level than the present was reached. Local glaciers might then readily have been formed in the extreme western sections of the State, or at least in Colorado, the movements and melting of which produced the drift and gravel beds that are found in so many places overlying the Loess. The rivers might then have been worn down much below their present level, and even, in places, to bed-rock. After the opposite or descending movement commenced, the rivers again silted up their beds. This silting up continued to recent times. At present the indications are that there is a slight

upward movement of this portion of the continent, amounting to perhaps one or two feet to the century.

The terraces made during this epoch occupy various heights above the flood-plains. The one next to the rivers in the interior ranges from three to six feet above the lowest bottom. The next is from twelve to twenty-five feet above the first, and a third at varying heights above the last. Often terraces intermediate between these are detected. They vary so much in height that the system ascertained to exist at one place is no guide for the next river. This variation, no doubt, is partly caused by one or two or more corresponding terraces being removed by subsequent erosion. They are the memorials of the rivers' former stay for an indefinite time at that level. It is possible that this Terrace Epoch was as long as the Loess period, but of this there is no certainty, as it partakes in part of the character of a lost interval of geological history.

Alluvium.—Next to the Loess deposits, in an economical point of view, the Alluvium formations are the most important. The valleys and flood-plains of the rivers and smaller streams, where these deposits are found, are a prominent feature of the surface geology of the State. All the rivers of the interior, such as the Platte, the Republican, the Niobrara, the Elkhorn, the Blues, the Nemahas, and their tributaries, have broad bottoms in the center or on one side of which the streams have their beds. The width of these bottoms seem to be dependent on the character of the underlying rock-formation. Where this is soft or yielding, the bottoms are broad, but where it is hard and compact they contract. This is, no doubt, one reason why the bottoms on the middle or upper courses of some of the rivers are wider than farther down.* These broad bottoms, as we have already seen, represent the ancient river-beds toward the close of the Loess age. It required many ages to drain the mighty ancient lake-bed; and when the present rivers were first outlined, the greater part of it was yet a vast swamp or bog. But, gradually, as the continent rose to a higher level, the rivers cut deeper and deeper, filling the whole flood-plain from bluff to bluff. Not until the drainage of this region was completed and the continent had reached nearly to its present level, was the volume of water so much diminished that the rivers contracted their currents and cut new beds somewhere through the present bottoms. The terraces, which are so numerous along many of the river-bottoms, indicates

*See on this subject Hayden's Report for 1870.

the slowness with which the land assumed its present form. The upper terraces were dry bottom when all the rest of the valley was yet a river-bed. It is probable that some of these bottoms were excavated during sub-glacial times, and afterward were filled up with *debris* when the continent had reached the lowest level. The great depth of sand and mud at the bottom of the Missouri, being from forty to one hundred feet below water along the Nebraska line before solid rock is reached, indicates an elevation of this region, when this was accomplished, far greater than it reached at any period during or immediately after Loess times. When this great lake commenced to be drained, the waters naturally took the direction and place of least resistance, which was the original bed of the river. If the Rocky Mountain system continues to rise, as it is believed to be doing, at the rate of a few feet to the century, although degradation may be equal to elevation, a time must come in the distant future when the Missouri will again roll over solid rock at its bottom.

As typical of the river-bottoms, let us look at the formation of the Platte Valley. The general direction of this great highway from the mountains to the Missouri is from west to east. This valley is from three to twenty miles wide in Nebraska, and over five hundred miles long. All the materials that once filled up this trough, from the tops of the highest hills on each side, have been, since the present rivers were outlined, toward the close of the Loess age, transported by the agency of water to the Missouri and the Gulf.* Here, then, are several thousand miles in area of surface entirely removed by denudation. Now the Platte comprises only a fraction of the river-bottoms of Nebraska. The Republican, alone, for two hundred miles has a bottom ranging from three to eight miles in breadth. The combined length of the main bottoms of the Blues, Elkhorns, and the Loups, would be over a thousand miles, and their breadth ranges from one to ten miles. The Nemahas and the Bows, and portions of the Niobrara, also add a great deal to the area of bottom lands. All these rivers have numerous tributaries, which have valleys in size proportionate to the main rivers, and these more than double the areas of bottom-land. The Missouri has, also, in some counties, like Dakota and Burt, contributed large areas of bottom-land to the soil of the State. These Missouri bottoms in Nebraska are exceptionally high, so that few

*See Hayden's Report for 1870.

of them have been overflowed since the settlement of the country. The one element of uncertainty about them is, when located near the river, the danger of being gradually washed away by the undermining action of the water. Sometimes during flood-time, when the current sweeps the bank, it is so insiduously undermined that, for several rods in length and many feet in breadth, it tumbles into the river. This cutting of the river is greatest when it commences to fall. Where the bank is removed on one side it generally is built up on the other. The old town of Omadi, in Dakota County, is an instance of this kind. So rapidly did the river cut into the bank, that many of the houses could not be removed, and fell victims to the flood. The river cut far enough to the west of the old site to leave it and its own bed, after being blown full of sand, to be grown up into a forest of cottonwood.

When now we bring into our estimate all the river bottoms of Nebraska, and the tributaries of these rivers, and reflect that all these valleys were formed in the same way, within comparatively modern geological times, the forces which water-agencies brought into play almost appal the mind by their very immensity. So well are these bottom-lands distributed that the emigrants can, in most of the counties of the State, choose between them and the uplands for their future home. In some of the new counties, like Fillmore, where bottom-lands are far apart, there are many small, modern dried-up lake beds, whose soil is closely allied to that of the valleys Not unfrequently is the choice made of portions of each, on the supposition that the bottom-lands are best adapted for the growth of large crops of grasses. But all the years of experience in cultivating uplands and bottoms in Nebraska leave the question of the superiority of the one over the other undecided. Both have their advocates. The seasons as well as the location have much to do with the question. Some bottom-lands are high and dry, while others are lower and contain so much alumina that in wet seasons they are difficult to work. On such lands, too, a wet spring interferes somewhat with early planting and sowing. All the uplands, too, which have a Loess origin, seem to produce cultivated grass as luxuriantly as the richest bottoms, especially where there is deep cultivation on old breaking. Again, most of the bottom-lands are so mingled with Loess materials, and their drainage is so good that the cereal grains and fruits are as productive on them as on the high lands. The bottom-lands are, however, the richest in organic

matter. The following analyses of these soils will give a better idea of their physical character. The samples were taken from what are believed to be average soils. The first is from the Elkhorn, the second from the Platte, the third from the Republican, and the fourth from the Blue River. The fifth is from an exceptionally wet and sticky soil, about two miles southeast of Dakota City.

	No 1.	No 2.	No. 3	No. 4.	No. 5.
Insoluble (silicious) matter	63.07	63.70	63.01	62.99	61.03
Ferric oxide	2.85	2.25	2.40	2.47	2.82
Alumina	8.41	7.76	8.36	8.08	10.52
Lime carbonate	7.08	7.99	8.01	7.85	7.09
Lime phosphate	.90	.85	.99	.94	.98
Magnesia carbonate	1.41	1.45	1.39	1.40	1.38
Potash	.50	.54	.61	.67	.60
Soda	.49	.52	.54	.58	.57
Sulphuric acid	.79	.70	.71	.79	.69
Organic matter	14.00	13.45	13.01	13.27	13.40
Loss in analysis	.50	.79	.97	.96	.92
Total	100.00	100.00	100.00	100.00	100.00

It is well known that many soils vary a great deal in chemical properties that are taken only a few feet apart, and therefore analyses often fail to give a correct idea of their true character. But from the above analyses, taken from widely distant localities, it is at least evident that chemically, alluvium differs from the Loess deposits principally in having more organic matter than alumina, and less silica. The depth of the alluvium varies greatly. Occasionally sand and drift materials predominate in the river bottoms, especially in the subsoil; sometimes the alluvium is of unknown depth, and again in a few feet the drift pebbles and sand of the subsoil are struck. This is especially the case in some of the western valleys which were worn down to the drift, and were not again subseqently filled up, though such cases are not often met with. There must have been a period of longer or shorter duration, when the bottoms were in the condition of swamps and bogs; and during this period the greater part of that organic matter, which is a distinguishing feature of these lands, accumulated in the surface-soil. It would be easy to select isolated spots, where the soil has forty per cent of organic matter; where, in fact, it is composed of semi-peat. When we reflect that this black soil is often twenty feet thick, it is appar-

ent that the period of its formation must have been very long. There are still some few localities where that formative condition has been perpetuated to the present time—as, for example, the bogs that are yet met with at the head-waters of the Elkhorn and the Logan, along the Elk Creek, on the Dakota bottom, and on the Stinking River, one of the tributaries of the Republican. In fact, along these tributaries all the intermediate stages from perfectly dry bottom to a bog can yet be found. But, so much has the volume of water been lessened in all the rivers of Nebraska through the influence of geological causes, that there are few places where now, even in flood-time, they overflow their banks. A curious phenomenon, illustrating through what changes of level and other conditions these river bottoms have passed, before reaching their present form, is the occurrence at various depths, of from ten to fifty feet, of great masses of timber in a semi-decayed condition. One such deposit on the Blue River bottom, near the mouth of Turkey Creek, successfully interrupted the digging of a well. So many thicknesses of logs occurred that it was found best to abandon the work already done for a new place. I have frequently observed trees, with trunks twenty to sixty feet long, sticking out from under the banks of the Missouri, where the soil had been freshly removed. It is possible that this timber accumulated in these places during the period when the rivers yet covered their entire bottoms, and when numberless trees must have been carried down during flood-time, and either stranded on the ancient sand-bars and mud-banks, or sunk to rise no more in the deeper pools and eddies which were rapidly filled up. The species, so far as I have yet been able to determine, from an examination of the half-decayed wood, are the same as yet grow in this region. They are principally cottonwood, elm, cedar, maple and walnut.

The Sand-Hills.

The sand-hills are an often-mentioned portion of Nebraska. They are found in certain sections of the western portion of the State. South of the Platte Valley they run parallel with the river, and are from one-half to six miles in breadth. A few are also found on the tributaries of the Republican. Occasionally slightly sandy districts are found as far east as the Logan, but they rarely approach even a small hill in magnitude. A few sand ridges are also found on the Elkhorn. North of the Platte, from about the mouth of the Calamus on to the Niobrara, they cover much larger

areas. They are also found over a limited area north of the Niobrara. Hayden (Report for 1870, p. 108) estimates the area of the sand-hills at about 20,000 square milas. From exploring the same region, I should not estimate them as so extensive, unless the fact be kept in mind that they are not continuous over the whole region. They are indeed found all the way for 100 miles west from the mouth of Rapid River, but in many places from eight to twenty miles south of the Niobrara there are spots where the soil seemed to be a mixture of Drift and Loess, and of high fertility, as was indicated by the character and rankness of the vegetation. Sometimes these hills are comparatively barren, and then again they are fertile enough to sustain a covering of nutritious grasses; so that this region is by no means the utterly barren waste that it is sometimes represented to be. It has been a favorite range for buffalo, and still is for antelope and deer; and, judging from their condition, the conclusion would be natural that this region could be used for stock-raising. In fact, already large herds of cattle are kept here. A great deal of the vegetation is peculiar to sandy districts. Some of the hills seem to have their loose sands held together by the *Ucca angustifolia*, which sends its roots down to a great depth. It probably marks a certain stage in their history. After this plant has compacted and given to the sands organic matter, the grasses come in and partially clothe the hills. The materials of these sand-hills are almost entirely sand, pebbles, and gravel, of varying degrees of fineness. The sand always predominates. Occasionally it is more or less modified by the presence of other materials, such as lime, potash, soda, alumina, and organic matter. These hills are in some places stationary, and so covered by vegetation that their true character is not suspected until closely examined. In other places again, especially in portions of the Loup and Niobrara region, they are so loosely compacted that the wind is ever changing their form, and turning them into all kinds of fantastic shapes. The most common appearance is that of a plain, undulating or hilly region, covered with conical hills of drifting sands. The smaller elevations frequently show a striking resemblance to craters. One such curious hill I found south of the Calamus, where the crater-like basin seemed to be compacted at once, and grown over with a species of wire grass. With the increase of rainfall and vegetation, the remodifying effects of the winds disappear.

Some eminent geologists have sought to account for these hills by the theory that the winds in the course of ages have blown the sand from the bars on the rivers until their accumulation caused these peculiar elevations. There are many difficulties in the way of this theory. East of Columbus no sand-hills are found, and it is hard to conceive how they should come to be limited to the western portion of the State if they were formed in this way. In some places at least the hills are partly composed of large pebbles and stones that could not have been moved by the winds. This is especially the case in some of these hills south and east of Kenesaw, in Adams County. I suggest, as a provisional explanation, the probability that, south of the Platte, the lines of sand-hills show the track of a current in the old lake that produced the Loess deposits. It is well known that fine sediment is deposited in still water, but coarse materials, such as sand and pebbles, in the borders and in tracks of currents. As the whole country rises toward the west, the water here may have veen very rapid, and the land in process of drying up when it was yet deep at its lower levels. Both causes, the currents and the winds, may have co-operated to produce these deposits. I am also satisfied that in some localities the sand-hills are nothing more than modified Loess deposits. They are Loess deposits, with all the alumina, organic matter and finest sand washed out of them. This at least seems to be the origin of some of the sand-hills on the Lower Loup, where they occupy a lower level than the Loess deposits. These two deposits so often shade into each other in the vicinity of the sand-hills, rendering it impossible to tell where the one begins and the other ends, that the theory of their common origin best explains the phenomena of these formations. After the western portion of the Loess deposits first became dry land, water-agencies were yet so powerful especially in flood times that much of it must have been remodified, and the coarser materials left to form sand-hills. And as we have already seen in another chapter, some of the sand and gravel hills partake largely of the Old World Kames, and may have been formed in the same way, especially as against these the Loess deposits abut. The sand-hills on the Upper Loup and the Niobrara probably derived the bulk of their materials directly from the Pliocene Tertiary deposits, which were mainly loosely compacted sands. This old Pliocene lake was probably perpetuated here down through Loess times to the borders of our own era. Even

yet lakelets are numerous over portions of this region, some of of which are alkaline and others fresh water. The latter can easily be distinguished from the former at sight by the thick vegetation growing around their margins, of which the former have very little, and sometimes not a trace. It is at least evident that these fresh-water lakes have had some common origin. Their fauna would prove it. The same species of fish and fresh-water mollusks are found in most of the large ones, even where there is no perceptible present outlet.

Although opposed to the views of eminent scientists, I have no doubt that many of these hills are capable of cultivation, and some day will be cultivated. In fact already many of them, that ten years ago were barren of vegetation, are now covered by a vigorous growth of grasses, and some that are favorably located are successfully included among the cultivated fields of adjoining farms. Notable examples of this can be seen south of Lowell. The transformation has been caused by the increasing rainfall of the State. Not all of them, indeed, will be utilized until the rich lands that border them are improved. But when better lands become scarce and costly, advances will gradually be made on the sand-hills. Already it has been proved that they produce corn, sweet potatoes and other root crops equal at least to the New Jersey sands. The rich marl beds in their vicinity will supply an inexhaustible source of fertilizing them.

Much has been done by geologists in exploring these sand-hills, still much more remains to be accomplished before all the causes that produced them are thoroughly understood.

Alkali Lands.

Every one in Nebraska will sooner or later hear of the so-called alkali lands. They are not confined to any one geological formation, but are found sometimes on the Drift, Alluvium, or the Loess. They increase in number from the eastern to the western portions of the State. Yet one half of the counties of the State do not have any such lands, and often there are only a few in a township or county. Where they have been closely examined they are found to vary a great deal in chemical constituents. Generally, however, the alkali is largely composed of soda compounds, with an occasional excess of lime and magnesia or potash. The following analyses of these soils show how variable they are. The first is taken

from the Platte bottom, south of North Platte; the second from near old Fort Kearney, and the third two miles west of Lincoln:

	No. 1.	No. 2.	No. 3.
Insoluble (silicious) matter	74.00	73.10	73.90
Ferric oxide	3.80	3.73	3.69
Alumina	2.08	2.29	2.10
Lime carbonate	6.01	4.29	3.90
Lime phosphate	1.70	1.40	1.49
Magnesia carbonate	1.89	1.29	1.47
Potash	1.68	1.80	3.69
Soda carbonate and bicarbonate	5.17	7.33	4.91
Sodium sulphate	.70	.89	.89
Moisture	.99	.98	.98
Organic matter	1.20	2.10	2.10
Loss in analysis	.78	.80	.88
Total	100.00	100.00	100.00

The specimens for analysis were not taken from soils crusted over with alkaline matter, but from spots where the ground was covered with a sparse vegetation.

Many of the alkali lands seem to have originated from an accumulation of water in low places, where there is an excess of alumina in the soil or subsoil. The escape of the water by evaporation left the saline matter behind, and, in the case of salt (sodium chloride), which all waters are known to contain in at least minute quantities, the chlorine, by chemical reactions, separated from the sodium; which latter, uniting immediately with oxygen and carbonic acid, formed the soda compounds.

These alkali spots are often successfully cultivated. The first steps toward their renovation must be drainage and deep cultivation. The next step is the consumption of the excess of alkali, which can be effected by crops of the cereal grains in wet seasons. In such seasons these alkali lands, if deeply cultivated, often produce splendid crops of grain. Wheat is especially a great consumer of the alkalies; and these being partly removed in this way, and the remaining excess mingled with the deeply cultivated soil, renders it, in many instances, in a few years capable of being used for the other ordinary crops of Nebraska. Treated in this way, these alkali lands often become the most valuable portions of the farm. There are comparatively few alkali lands in the State that cannot be reclaimed in this way.

Hard Pan.—Gumbo Soil.—One of the peculiar deposits of the State is known among the people as hard pan, and in some places as gumbo soil. It never occurs in this State over extensive areas. In some few counties and townships it occurs in spots—sometimes on bottoms and sometimes on level uplands. The areas covered by it range in extent from a few yards to several acres. Sometimes these spots lie slightly below the general level of the land, and in places shade insensibly into what are known as clay and wet lands. There are a few townships in the south part of Cedar, Knox, and the north part of Pierce counties where occasional sections occur that have a spotted appearance which is produced by these "gumbo soils." They are easily recognized by the paucity of the peculiar blue and wire grasses that cover them. More rarely they are covered by from two to six inches of alluvium or ordinary upland soil, and only give indications of their presence when an attempt is made at their cultivation. They "bake" and become exceedingly hard when dried. The most compact of these soils are plowed and cultivated with great difficulty. The following analyses indicate their composition. The first is taken from a specimen on Salt Creek bottom, and the second from the lower Nemaha:

	No. 1.	No. 2.
Insoluble (silicious) matter	27.11	20.67
Ferric oxide	4.32	2.83
Alumina, clay	50.11	57.30
Lime carbonate	8.21	9.08
Lime phosphate	1.09	.88
Magnesia carbonate	1.45	1.70
Potassa	1.98	.67
Soda	.83	1.80
Organic matter	1.30	2.01
Moisture	2.90	2.09
Loss in analysis	.70	.87
Total	100.00	100.00

This analysis shows that these soils contain clay in excess. From many other analyses which I made, only to ascertain the amount of clay that was present, it was found to vary from fifteen to sixty per cent. The quantity of all their constituents varies a great deal, but they all in common contain a large amount of clay. A few contained a perceptible quantity of manganese. From these analyses it is clear what is needed to redeem them or make them tillable

—they should be mingled with silicious matter, and often the soil below them will answer for this purpose, as frequently they are only a few inches thick.

The Bad Lands.—These have already been discussed and described under the Miocene Period. They deserve a reference here because they constitute all that there is of the surface beyond the White Earth River, in the northwest corner of the State. As already stated, this section is made up of Miocene rocks. The surface materials here are mostly made up of white and yellowish indurated clays, sands, marls, and occasional thin beds of lime and sandstone. When going through these Bad Lands I observed these lime and sandstones to appear and disappear in the most unexpected manner, indicating a great variety of conditions under which they were formed. Hayden first made known these wonderful regions. It is hard to realize the grandeur and uniqueness of this region without visiting it—this, at least, was the case with myself. Here in the deep canyons, at the foot of the stair-like projections, the earliest of those wonderful fossil treasures was found which have been described by Leidy, and which have done so much to revolutionize our notions of the progress of life and of Tertiary times.

Agriculture in such a region as this, where comparatively little is now growing, is of course impracticable. The scanty grasses, however, can be, and are beginning to be—at least on the borders of this region—utilized for pasturing stock. Even here rainfall is increasing, as is indicated by a great increase in the quantity of grass that is spontaneously produced. Whether this region can ever be utilized for the purposes of agriculture, even when once the rainfall is sufficient, is a problem for the future. Regions as rough have been cultivated by hand. Whenever in the distant future population crowds in this direction, and the rainfall has sufficiently increased, even these Bad Lands can be fertilized, if they need fertilization, by the immense quantities of natural fertilizers, such as marl, that here abound. In the mean time it will be utilized for pasturing stock. Though this region is so unattractive to the utilitarian, I doubt whether any other equal area of Nebraska will be of more benefit to mankind, simply because here we have outlined so marvelously the old life of Miocene times, and it must ever be a stimulus to geological studies, and those grand results which scientific culture produces. No novel can be as interesting to a thought-

ful mind as Hayden's and Leidy's descriptions of these Bad Lands and their animal remains.

Fuel from the Surface-Deposits.

It is not yet absolutely settled, as already stated, how much dependence can be placed on the coal-supplies of the Carboniferous, Cretaceous, and Tertiary deposits, in each of which thin beds have been found and worked to a limited extent. Hayden and Meek incline to the opinion that no beds of coal thick enough and of sufficiently good quality to be profitably worked will be found in the State. (Hayden's Report for 1870, p. 134, etc.) This subject has already been discussed in the chapter on Carboniferous Age. There is, however, no question about the great quantity of peat in Nebraska, which subject is discussed in the next chapter.

Water Resources of Nebraska.—This subject, which would naturally come in here, is omitted in this connection, as it has already been fully discussed in the chapter on Physical Geography.

Timber in Modern Geological Times.—It is natural to suppose from well-known natural causes that when the Loess age was drawing to a close, and the lower portions of the area covered by these deposits were yet in a condition of a bog, the climate was much more favorable than the present for the growth of timber. Rainfall and moisture in the atmosphere must then have been much more abundant. In July, 1868, while walking along the edge of one of the Logan peat-bogs in Cedar County, my jacob staff struck some hard body in the peat. Examining it more closely I found a log buried in the peat at least sixty feet in length. Following up this discovery with a careful search, I found in this and other bogs a great many buried logs of various length and thickness. Most of them were found where there was no existing timber within twenty miles, and from which they could not have floated in flood-times. I regret that I had no means of extricating some of those logs, and ascertaining the species to which they belonged. That would no doubt have thrown much light on the changes that have taken place since they were buried in the bog. But they evidently grew on the shores or banks, and after falling into the bog they were protected from decay by the well-known antiseptic properties of peaty waters. Another fact that shows the greater prevalence of timber within geologically recent times is the remnants of old pine forests yet buried in the ground. In the summer of 1868, when

traveling along and near the Niobrara, roots of pine trees were often found sticking in the ground, more than fifty miles south and east of the present forests of this timber. Often did these old roots furnish me with the materials of a camp fire. At no very remote period pine forests must have flourished down to the mouth of the Niobrara. Many other facts, of a similar character, seem to leave no room to doubt that in geologically recent times far more extensive forests prevailed all over Nebraska than those which now occupy the ground. What caused their disappearance can, perhaps, not be certainly determined. Some geologists hold that the increasing dryness of the climate caused the disappearance of any old forests that might have existed. But might not the converse of this also have been true here, as well as elsewhere, namely, that the destruction of forests inaugurated the dry climate that prevailed when this territory was first explored? It is at least conceivable that the primitive forest received its death-blow in a dry summer by fire, through the vandal acts of Indians in pursuit of game or for purposes of war. What suggested this theory as a possible explanation of the disappearance of forests on this territory, was the finding of pine roots before referred to, and often, when partially buried, showing marks of fire from carbonized ends, and in localities so sandy, and where vegetation was so scant, that an ordinary prairie fire was out of the question. An old tradition that I once heard from the Omaha Indians points to the same conclusion.

It is wonderful how nature here responds to the efforts of men for reclothing this territory with timber. Man thus becomes an efficient agent for the production of geological changes. As prairie fires are repressed and trees are planted by the million, the climate must be still further ameliorated. When once there are groves of timber on every section or quarter-section of land in the State, an approach will be made to some of the best physical conditions of Tertiary times. The people of this new State have a wonderful inheritance of wealth, beauty and power in their fine climate and their rich lands, and as they become conscious of this they will more and more lend a helping hand to the processes of nature for the development and utilization of the material wealth of Nebraska.

Causes of Changes of Climatic Conditions During the Quaternary Age.—Every geologist has noted the fact that there have been very many changes of climate during the progress of the world's history.

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Even in Arctic regions there are many evidences of the prevalence at different times in the past of temperate and even semi-tropical climates. In Grinnell Land Dr. Hayes obtained corals and chambered shells, which indicate that warm oceans once obtained there. The adjoining lands at the same time nourished a most luxuriant vegetation. We have seen that in our own State there have been, even in Cenozoic times, semi-tropical conditions, which very gradually disappeared and gave place to Arctic and again to warm, temperate climates. It is a fact, therefore, that climates rotate throughout the geologic ages. The old idea that the earlier warm climates were produced mainly by the then higher temperature of the interior of the globe, and that the colder modern conditions have been brought about principally by gradual cooling of its mass, is now almost universally abandoned. The earth still radiates heat, as it always has done, but its effects are not now—and it is doubtful whether, during recorded geological time, it has been perceptible. In all times climates have varied in proportion to the heat which the globe received, directly or indirectly, from the sun. Even in the Silurian the climates were probably as well marked as now. The question then eventually rises, what is it that causes the variations in the climates of the globe? My limits only permit me to refer to those explanations that have received the most attention, and which, in my judgment, are the most probable.

The theory accounting for climatic changes which has been sanctioned by the greatest number of geologists during this generation was proposed and defended by that prince among naturalists, Lyell. He referred to the admitted fact that through the geological ages sea and land have many times changed places—that it is hard to find a place where the billows of the ocean did not formerly roll—that all the strata formed since the opening Laurentian are only so many fossil sea bottoms. Even now some coast lines are sinking and others are rising, and a continuation of these changes will engulf some existing lands and raise some sea bottoms above the water. Even the relative levels of closely-joining land masses slowly change in this way. When, therefore, we are required by Lyell's theory to believe that the relative distribution of land and water was formerly very different from what it is now, no one questions the facts on which this theory is based. If now such changes were brought about that the principal land masses should be placed in equatorial regions, the mean temperature of such high northern lands as were

left would be raised sufficiently to produce the cypress, sequoia, fig tree, and even the palm. Such a vegetation under these circumstances might flourish within the Arctic circle. A heated equator would send warm currents of air and water to heat up the polar regions. Some such conditions Lyell thought existed, for example, during the Miocene, or earlier still during the Carboniferous, when tree ferns grew on islands in Arctic regions. Lyell considered the atmosphere to be the chief instrument for the distribution of heat. On the other hand the prevalence of polar continents and an oceanic equator produced arctic conditions in all high latitudes. The progress of discovery, however, has brought to light many facts which cannot well be reconciled with this theory. Among these facts are intercallated beds representing mild conditions of climate in the midst of and during glacial times. The most conspicuous example of this is the Old Forest Bed already spoken of. Even in Arctic regions tree trunks have been found in the midst of glacial debris* It is also questionable whether the atmosphere flowing northward from tropical land masses would heat up the poles. Its heat would be dissipated long before reaching the extreme north. At the present day western America receives its high temperature, not from the tropical winds, but from the breezes that blow over the Japan current, as western Europe is warmed by the Gulf Stream. Eastern Europe and Asia receive no benefit from these warm winds—they are cooled long before they reach the great interior. It is also extremely questionable whether there ever was exactly, or even approximately, such a distribution of land and water as this theory calls for. Many other objections are urged against Lyell's theory. Geologists, therefore, now look for the causes which produce changes of climate to cosmical rather than to terrestrial influences.

The cosmical theory that would explain the phenomena of climate that is now receiving most attention was proposed by and is still ably defended by James Croll, and is also maintained by James Geike, both connected with the Geological Survey of Scotland. According to this theory, two causes are chiefly operative—the changing eccentricity of the earth's orbit and the precession of the equinoxes. Leverier's calculations make "the superior limit of the earth's eccentricity 0.07775." At the present time it is lessening, and will continue to do so for 23,900 years, when its value will be .00314; after which it will again increase. These changes of eccen-

*See James Geike's Great Ice Age, page 462.

tricity may affect climate in two ways. " It may increase or diminish the difference between the summer and winter temperature." Take for example the second case. When the eccentricity is greatest the distance of the earth from the sun, when in aphelion, or farthest away, is 98,506,350 miles; and when in perihelion, or nearest to the sun, it is only 84,293,650 miles. The earth is, therefore, during such times, 14,212,700 miles further from the sun in aphelion than when in perihelion. This is a greater difference by many millions of miles than now obtains. During such a period of high eccentricity when winter occurs in aphelion, it is also longer by 36 days than the summer. At the present time the difference between the length of winter and summer (from the 22d of September to the 20th of March, and from the latter date to the 22d of September) is only seven or eight days. Given, therefore, a winter 36 days longer than the present, with the sun from 8,000,000 to 14,000,000 of miles further away from the earth than now, and the mean temperature of the globe would not, indeed, be greatly lowered, but the conditions of its reception would be vastly different. One-fifth less heat would be received in winter and one-fifth more in summer, which latter would be exceedingly short. A long, cold winter and a short, hot summer would be the result (Croll). What snows fell during autumn, winter and spring, would not be dissipated by the short, hot summer. Snow would accumulate and gradually form glaciers of immense thickness. An indirect result affecting climate greatly would be a change of the oceans' circulation. The warm currents that now lave northern zones would be largely excluded from the glaciated hemisphere. While, however, one hemisphere would be glaciated, the other would have its winter in perihelion and its summer in aphelion. This condition, according to Croll and Herschel, would " annihilate the difference between winter and summer in temperate latitudes." 'Owing to the precession of the equinoxes, these conditions would change from north to south of the equator every 10,500 years, or thereabouts. Such periods of high eccentricity occurred three times during the last 3,000,000 years—the last one commencing 240,000 years ago and ending 80,000 years ago, embracing a period of 160,000 years. The cold and glaciation was most intense between 30,000 and 40,000 years after it commenced.' (Geike.)

As the earth's orbit will continue to grow less eccentric for 23,900 years, during that time, at least, if this theory for the pro

duction of varying climates is correct, the extremes of temperature will also gradually become less, and continually milder conditions will prevail. All the changes that may occur hereafter, therefore, for a long period will be favorable, and the globe as a whole become more and more fitted for a theatre for the development of mind and morals.

Even if this explanation of the causes of climatic changes is not the correct one, there can be little doubt that some cosmical influences will in the end be found to furnish the key to unlock the mysteries of these changing phenomena.

CHAPTER X.

ECONOMICAL GEOLOGY.

Coal, Bituminous and Lignite.—Peat, its Quantity, Quality, and Where and How Formed.—Building Stone, Where and How Found; their Character at South Bend.—Building Stone in the Cretaceous and Tertiary.—Lime and Hydraulic Cement.—Its Manufacture at Beatrice. Brick Clay.—Fire Clay.—Potters' Clay; Sections and Character of at Louisville.—Kaolin.—Gypsum, Where Found and How it Occurs.—Silica, its Great Extent and Character.—Iron Ores.—Zinc and Lead.—Gold.—Marl Beds.—Salt, Where and How it Occurs.—Artesian Well in Lincoln and its Medicinal Character. Artesian Wells over the State; their Future Value and Importance.

Coal.—Bituminous coal has already been discussed in the chapter on the Carboniferous measures; and lignite coal in the chapter on the Cretaceous deposits.

Peat.—There is no question about the great quantity of peat in Nebraska. Hayden mentions many localities where it is found. (Report for 1867, 1868, and 1869.) It is also found on the tributaries and head-waters of the Logan, the Elkhorn, the Blue, and on Stinking River, and other tributaries of the Republican. Great quantities are also found in Boone County, on the Loups, and on their tributaries. In fact, there is hardly a township in some sections of the State that does not contain some peat-bogs. When people once learn its value, and more attention is directed to it, it will be found where now it is not expected. One peat-bog on the

Logan (township 28 north, 1 and 2 east) is five or six miles in length and of variable breadth. I could find no bottom to this bog with a fifteen-foot pole. This peat I personally tested and found to be of excellent quality. In fact, nearly all the peat that I have tested in this State is fully up to the average in quality. A singularly good article is found at Pittsburgh, on the Blue River, where the deposit is also quite extensive. Among the animal remains submitted to me for examination from this bed was the molar tooth of the gigantic beaver (*Castor ohioensis*), proving that this animal existed in Nebraska in times geologically recent. The most of the peat beds that I have examined seem to have been formed in lakelets that gradually became bogs by an accumulation of vegetable matter derived from coarse grasses, sedges, rushes, polygonums, duck-weeds, pond-weeds, arrow-weed, etc., lilies, etc. Sphagnum which seems to form the mass of organic matter in peat-bogs of granitic and silicious districts, only occurs in Nebraska in a bog near Curlew, in Cedar County, and one or two other places in the same region. At least I found it nowhere else. Many of these peat-bogs are now so far advanced as to be dry enough to be wagoned over in midsummer, but through the middle of which a stream of water is still flowing. Others have no visible outlet, but retain the water poured into them, when the spring and June rains fall, during the remainder of the year, and thus supply the conditions necessary for the peculiar vegetation of such formations. Sometimes, too, depressions in the surface where peat is forming are supplied with moisture from ever-flowing springs. The beginnings of many of these peat-beds date back at least to the close of the Loess age, so that sufficient time has elapsed for the accumulation of great quantities of this material. Peat can be cheaply taken out of a bog with a spade, and laid up like cord-wood under cover to dry, when it is ready for use. The objections to using it thus prepared is its liability to crumble. Unfortunately, to prepare it by molding and pressing requires some capital for apparatus, and this is one reason why these beds have not yet been worked. In some places, too, wood-fuel is yet cheap, and in others coal from abroad is easily obtained, and these causes have also operated to delay the use of peat for fuel. But such treasures cannot remain unused forever. Eventually this peat must be utilized, and if it is cheaply furnished, as it can be, the State will be supplied for a long time from its own territory for manufacturing purposes and domestic use, with all the fuel needed. (For an

able discussion of peat in Nebraska, see Hayden's Final Report of Geological Survey of Nebraska, p. 69.)

Building Stones.—In portions of Nebraska building stones are abundant. In the central and western portions of the State they are difficult to obtain, owing to the great thickness of the superficial deposits, which must be removed in order to reach the underlying rocks. This is easiest done along the edge of bluffs or ravines, where they are often partially exposed.

The Carboniferous section of the State is, on the whole, the richest in building stones. Here limestones, silicious limestones, and many kinds of sandstones of all shades and colors abound. In Richardson County there are many fine quarries, and those at Salem are among the best. Here two beds of limestone are exposed, which generally extend under the superficial deposits. These strata are exposed in many other places in this county. In Pawnee County the building stone is still more abundant. Beds from six inches to two feet in thickness crop out on hill-sides in many places. One of the best crops out about eight miles west of Pawnee City. It is cream colored, and soft, but of great tenacity. It is a fusulina limestone, can be worked into any form with ease, and is a great favorite with builders. Hayden regards it as of Permo-Carboniferous age. In Gage County there are various beds of soft, yellow limestone, full of geode cavities, porous and spongy; and also of compact limestone, which are used for building purposes.

Johnson County contains a silicious limestone of various thickness, which is almost wholly composed of fusulina. The court house in Tecumseh, is constructed of this material. It is exposed at many places along the hillsides, and is easily quarried and worked. In Nemaha and Otoe counties, along the Missouri River, there are various beds of stone that are quarried and used for building. One of these is a limestone, and at Peru it occurs near the top of the bluffs. Further down at Brownville, there is a bed of limestone three feet thick, of very superior quality for building purposes. Fine-grained, micaceous sandstone that readily cleaves into flags, also exists here. Towards the center of the county some fine quarries have been opened. The church at Febing is an example of the quality of its stone and its fine architectural effect. Similar exposures of rock, suitable for building materials, occur along the Missouri through Otoe and Cass counties. One of the best is below Plattsmouth, on the banks of the Missouri. Here

are some of the finest massive limestones in the State. The upper surface, where the superficial deposits are removed, are worn as smooth as mirrors, and exhibit the parallel striæ so characteristic of glacial action. Unfortunately, the great thickness of the superficial deposits here makes these quarries expensive in working. At La Platte, near the line of the Burlington & Missouri Railroad, there is another remarkable quarry of fine-grained, slightly silicious limestone. It contains innumerable impressions of fusulinas. The government architects selected the stones from this quarry with which to build the United States post-office and court house in Lincoln. It successfully stood the severest mechanical and chemical tests. Farther up the Platte and on its north side, opposite South Bend, W. B. Stout, Esq., has opened a new quarry during the last year. Here occur several strata of unusually massive limestone, one, of which, eighteen inches thick, is partially oolitic and partly filled with fusulina. Near the middle there is a layer of intensely hard nodules of silicious matter. The limestones in this quarry are of exceptional purity. They take a very fine polish. On the whole, it is the best stone quarry that I have yet visited in the State. Some of the piers in the new railroad bridge at Plattsmouth were constructed of this stone. The contractor is also using it in the construction of the new capitol wing at Lincoln. Other fine quarries are also opened on the south side of the Platte in strata of a similar character. East of Lincoln, on the Nebraska railroad, at Syracuse and at other points, there are quarries of impure, variously colored limestone of considerable thickness, from which immense quantities of building stones have been obtained. From these quarries and from similar ones on the Atchison & Nebraska Railroad, a little southeast of Lincoln, the stones were quarried for the State penitentiary.

The Cretaceous rocks of Nebraska also furnish a large quantity of excellent building stone. Those of the Dakota Group are mostly silicious. They are of all shades of yellow and brown, sometimes approaching to a cream color and white. They furnish the hardest and the softest stone in the State. The softer varieties are unfit for building stone. Large quantities, however, are a medium between the two extremes, and are very valuable for smaller structures, owing to the ease with which they can be quarried and dressed. In Dakota County, in this group, occurs the intensely hard quartzite which has been used in Sioux City, Iowa, for the foundation of

some of their largest brick blocks. The best quarry of it that I have examined is that of Hon. J. Warner in Dakota County. This group also furnishes building stones in portions of Dixon, Burt, Dodge, Washington, Saunders, Lancaster and Gage Counties. The rocks of the Niobrara Group which occur above those last mentioned are mostly limestone more or less pure. One of its beds called from the abundance of its fossils the Inoceramus bed, often breaks up into flagging stone. It forms good building materials, is easily worked, and is capable of resisting great pressure. Along the Missouri it is first seen on the hill tops in Dakota County, and increases in thickness northward and westward. It extends in a southwestern direction across the State into Kansas. Over the Inoceramus beds in Cedar and Knox counties, there is an immense thickness of massive chalk rock. In a few places it is almost as pure as the chalk of commerce. It varies in color from light blue, and the various shades of yellow, to almost white. It can be easily sawed and planed into any shape. Though soft, it does not disintegrate on exposure, but appears when exposed to grow harder with age. Some houses built of it on the Santee Agency in Knox County, twenty years ago, show no sign of crumbling. Some equally old houses, built of this chalk rock, in Yankton, D. T., are still intact. The various rocks of the Niobrara Group furnish building materials in Cedar, Knox, Wayne, Cuming, Colfax, Stanton, Butter, Saunders, Seward, Jefferson, Nuckolls, Webster, Franklin, and some other counties.

West of the Cretaceous deposits the Tertiary beds occupy the State to its very borders. The superficial deposits here generally conceal the rocks, but as already observed where they are exposed, there are some silicious beds, and silicates of lime that answer for foundation stone. This is notably the case along the Republican River and its tributaries, and on some of the tributaries of the Loup and the Niobrara. But this section of the State has not yet been sufficiently explored to indicate sharply where building stones may be found.

Lime and Hydraulic Cement.

As already stated, limestone is abundant in the Carboniferous and Permo-Carboniferous measures of the State. The Niobrara Group also furnishes an unlimited supply of it. A curious phenomenon of the limestone of the Carboniferous and Permo-Carboniferous, is that nearly all of it is more or less hydraulic. This is proba-

bly owing to the presence of greater or less quantities of carbonate of magnesia, and a little alumina. In some sections the hydraulic limestone is of very good quality. At Beatrice its manufacture was for some time conducted, but owing to various causes it has been temporarily suspended. All the work done with this cement has stood the test of time. Owing to inadequate appliances it was not sufficiently pulverized, but that defect will be remedied when its manufacture will be resumed. This will probably be done during the coming season. Sooner or later it must become an important industry of the place and the State.

Brick Clay of good quality exists in every part of the State. The Loess deposits which are so widely distributed over the State furnish it in abundance. The only precaution needed is to select it where there are no concretions of lime. Beneath the Loess and the adjoining drift in many places is a greater or less thickness of clay of glacial age that makes first-class brick. There are also occasional strata in the alluviums of the river bottoms that furnish brick clay in abundance.

Fire Clay is also abundant. It underlies and sometimes overlies the thin beds of coal in southeastern Nebraska, and is found at long intervals in other sections of the State.

Potters' Clay is occasionally found in the alluvium. In former years a bed was worked on the Missouri bottom, east of Dakota City. The best now known or worked is located at Louisville, in Cass County. The following is a section:

1. Loess.. 3 feet.
2. Red rock; Dakota Group ....2 to 3 "
3. Potters' clay, of greyish white color, with streaks of pure white sand from one to eight inches thick.................................20 "

The bottom of this clay has not yet been reached. Three miles east of this bed another occurs of which the following is a section:

1. Black soil... 2 feet.
2. Bluish potters' clay with lime concretions towards the top......12 "

One mile and a half northeast of the first another bed occurs. The following is a section:

1. Black soil .... 5 inches.
2. Reddish earth...18 "
3. Potters' clay, exposed.. 6 feet.

A fine article of stone pottery is now turned out at this place which, because of its excellence, has a large sale. The third section now furnishes the greater part of the clay that is used in the manufacture of pottery. It is not quite so light colored as that from the first, but fewer cracks occur in burning. Similar beds that can be utilized in this way no doubt occur elsewhere in the huge beds of blue clay that abound in the State.

Kaolin has been reported from various parts of the State. The best that I have seen is that from Webster County, and from Louisville, in Cass County, on the line of the Burlington & Missouri Railroad. The latter is in conjunction with the potters' clay already spoken of. From its chemical constitution it will no doubt stand the test of experience.

Gypsum (sulphate of lime) exists in many places in the Cretaceous measures of the State. In Northern Nebraska, and especially in Dakota, Dixon, Cedar and Knox Counties, along the Missouri bluffs, there are innumerable crystals in leaf-like forms. Often they assume the shape of a cross. No other localities in the Union furnish more beautiful forms. Generally they are transparent, though occasionally coated with oxides of iron. In the Fort Pierre Group, exposed on the hill tops near the town of Niobrara, and on the Republican, these crystals glimmer in the distance, and have given the name of Shining Hills to the country further up the Missouri.

Mineral Paint—Ochre.—Along the Missouri from Plattsmouth to Brownville, and further down, there are immense deposits of mineral paint, or ochre. It is of different hues—dull red, various shades of brown, yellow, and other colors, according to the amount of iron that is present. Some of the beds are from three to five feet thick, and of as fine a quality as any in the market. There are also large beds of ochre in the Cretaceous deposits along the Republican and on the Missouri in northwestern Nebraska. As flax culture is one of the most successful industries in the State, because of the ease with which it is grown and its superior quality, the manufacture of mineral paint can be inaugurated on a large and profitable scale, especially as oil mills and white lead works are in successful operation in Omaha.

Silica.—Although silica is one of the most abundant of minerals, it is rarely found in so fine a state as in some sections of Nebraska. Some most remarkable deposits of it exist along the Republican.

These are often in combination with alkalies, and have already been discussed in the chapter on the Pliocene. Fine beds also exist on the Loup, Elkhorn, Logan, and Oak Creek. The great beds of sand on the Platte contain some organic matter, and the sand itself is contaminated more or less with iron, which is the character of many other deposits in the State. The beds on the Elkhorn above West Point are noteworthy for their purity. The drift in many places abounds in beds of pure sand, and the principal difficulty in obtaining it comes from the thickness of the overlying Loess. In the Pliocene Tertiary region where cuts, ravines or bluffs exist, all grades from very fine to coarse can readily be obtained.

Lithographic Stone, of Upper Carboniferous age, exists near Syracuse, in Otoe County. It is of medium quality. The extent of the deposit has not yet been ascertained, but the indications are that it may be sufficient to make it of mercantile importance.

Iron Ores have not yet been found in beds thick enough to work. The limenite of the Dakota Group, which is the best ore in the State so far as known, occurs only in thin layers of a few inches in thickness.

Zinc and Lead are frequently found in small quantities, but nowhere yet has enough been obtained to justify extensive prospecting. The geological indications are not favorable for their presence in large quantities anywhere in the State.

Gold in minute quantities is occasionally found in the sands of the Platte, Nebraska, and other streams. But as our geological formations are all more recent than those producing gold, we have no scientific reason to suspect its existence within our borders. The minute quantities along our river beds no doubt came from the mountains by drift agencies.

Marl Beds are exceedingly abundant in some sections of Western Nebraska. They are specially characteristic of the Tertiary deposits, and vary a great deal in character and in appearance. The dominant colors are greenish, yellowish, and whitish. They are beautifully exposed on the driftwood south of Culbertson, close by the river bank. Here there are sections of marl exposed, from four to eight feet in thickness, and of green and yellow color. The green marls are specially rich in potash and iron, and their various compounds. Similar beds are found in many other places along the Republican and its tributaries as far as to the western line of the

State. They are also common on the Niobrara, on tributaries of the Loup, and in other sections. As the sands of New Jersey have been fertilized, and in many places transformed into gardens by marl beds, so can the occasionally excessively sandy tracts of Western Nebraska also be changed into rich lands when once the needs of population make it necessary.

Salt in large quantities exists in a few sections of the State. In Lancaster County there are a number of salt marshes, the one near Lincoln covering about six hundred acres. There are a number of smaller ones near by. They are nearly level and in dry weather are covered with incrustations of salt. They are mostly destitute of vegetation. Fine sand and loam comprise the soil, underlaid, however, by the reddish sandstones of the Dakota Group. In the deposits of this marsh, and all the others that I have visited, are the bones of elk, deer, antelope and buffalo, which no doubt were mired in past times when they resorted here for salt. Over this marsh the water oozes up at innumerable places, and great quantities of it flow off into Salt Creek. Wherever I have tested it the brine contained within a fraction of ten per cent of salt. Oftener more than less. Much of the brine over this marsh that has stood for days and partly evaporated, contains from twenty to thirty per cent of salt. A number of vats have been constructed here and the manufacture of salt is carried on on a small scale. The business is capable of immense development. Artesian wells that have been put down at and near this place have struck brine at different depths, the saltiness varying from five to twenty per cent. The well on the Government Square is one thousand and fifty feet deep. It passed through various strata which furnished brine and mineral waters of remarkable quality. The mingling together of all the streams that flow constantly from this well, furnishes a mineral water which for efficacy in healing some kind of diseases, is believed not to be surpassed by any medicinal waters of the land. At the Commercial Hotel, in Lincoln, this artesian water is employed in giving Turkish and other baths. Remarkable cures have already been performed through its agency.

In northwestern Nebraska, beyond the head-waters of the Elkhorn, there is another region of salt springs and marshes far more extensive than the one in Lancaster County. Unfortunately it is beyond the railroad lines, and in a sparsely settled region. It has not yet been thoroughly explored. In various other places brine

has been found in boring for fresh water. There is no doubt, if the saline resources of the State were developed, the home supply would be abundant for ages.

Artesian Wells.—The artesian wells now flowing in Lincoln, and the one in successful operation in Omaha, are demonstrations of the ease with they can be obtained. The former is over 1,000 and the latter 750 feet deep. Water, however, flowing to the surface was first obtained in the former at a depth of 550 feet. The geological structure of the State is most favorable for obtaining water in almost every quarter of it, and eventually it will be found that artesian wells will supply an immense amount of the cheapest motive power. It can be run into huge reservoirs, and let fall from heights sufficient to propel large water wheels. Their value in the interior for watering stock and other purposes will be incalculable.

APPENDIX.

The following are the most important works hitherto published giving an account of or referring to the natural history of Nebraska:

1. Lewis and Clarke's Expedition to the Head Waters of the Missouri, 1804–1806.
2. Explorations of Fremont, 1842 and subsequently.
3. Reports of the Union Pacific Railroad Surveying Expeditions from 1853 to 1856.
4. Geological Report of Wisconsin, Iowa, and Minnesota, by David Dale Owen, 1852. Contains some descriptions of vertebrates from the Bad Lands and of Carboniferous fossils.
5. Swallow's Reports on Fossils of the Carboniferous Deposits.
6. Geinitz's (Dresden) Carboniferous and Dyas of Nebraska, 1866.
7. Marcou's Report on Carboniferous of Nebraska, Bull., Geol., Soc. France; second series, volume 21.
8. Hayden's Report for 1867, 1868, and 1869.
9. Hayden's Report for 1870.
10. Hayden's Final Report, 1872.

Cretaceous Geology.

11. Hayden's papers in American Journal of Science and Arts from 1863 to 1867.
12. O. Heer's (Switzerland) Phyllites du Nebraska, 1865.
13. Some Cretaceous Fossil Plants of Nebraska, by Lesquereux, 1868.
14. Newberry's Late Extinct Floras of North America, Lyceum of Natural History of New York, 1868.
15. Lesquereux's Cretaceous Flora, 1874. This work contains all the descriptions of Cretaceous leaves from Nebraska, Kansas, etc., previously published.
16. Cretaceous Vertebrata, E. D. Cope, volume 2, 1875. Though describing mainly from Niobrara Group of Kansas, its descriptions are good for many forms from the same horizon in Nebraska.
17. E. B. Meek's Invertebrate Paleontology of the Cretaceous of the Northwest; volume 9.

Tertiary Geology.

18\. Leidy's Ancient Fauna of Nebraska. Smithsonian publication, 1852.

18\. Leidy's Mammalian Fauna of Dakota and Nebraska; 1879, published by the Academy of Natural Sciences of Philadelphia; volume 7, second series.

20\. Tertiary Flora, by Lesquereux; 1878, volume 5.

21\. Superficial Deposits of Nebraska, by S. A.; 1874.

General Natural History.

22. Birds of the Northwest, Coues; 1874.
23. Faunal List and Natural Food of the Birds of Nebraska, by S. A.; 1877.
24. Report of U. S. Entomological Commission; 1877.
25. Catalogue of the Flora of Nebraska, by S. A., published by the University of Nebraska; 1875.
26. Catalogue of Land and Fresh Water Shells of Nebraska, by S. A ; Bulletin of Geological Surveys of the Territories, 1876.

Of the above publications the following numbers were published under the direction of the Hayden Surveys, by authority of the government, namely: Numbers 8, 9, 10, 15, 16, 17, 20, 21, 22, 23, 24, and 26.

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